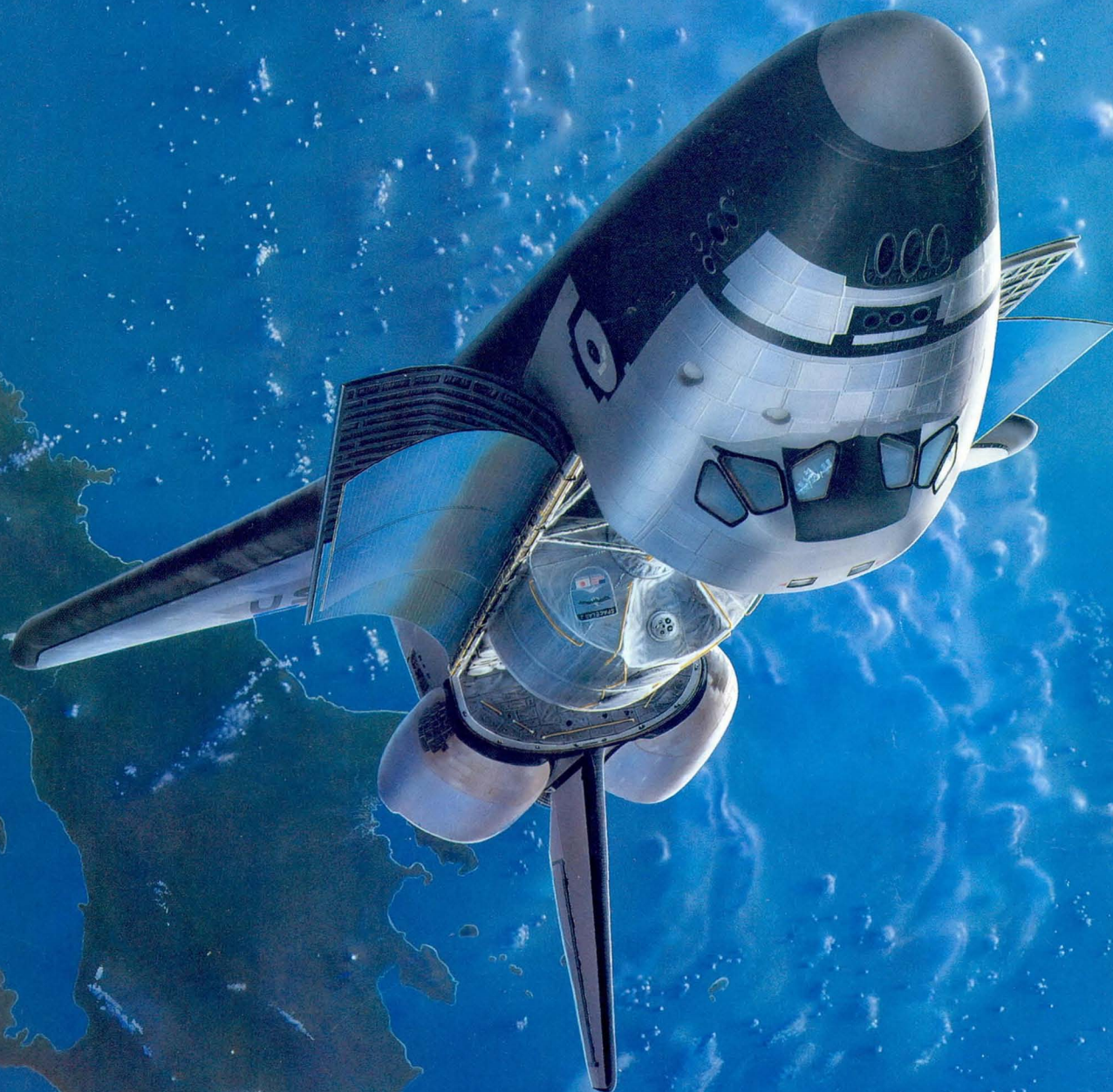


Spacelab J



- Microgravity Sciences
- Life Sciences

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The Spacelab J mission exemplifies international cooperation in space. Using Spacelab, which was built by the European Space Agency (ESA), the National Aeronautics and Space Administration (NASA) and the National Space Development Agency of Japan (NASDA) are conducting investigations in microgravity and life sciences. During the 7-day mission, 43 experiments will be performed in the Spacelab long module.

NASDA's portion, known as the First Materials Processing Test (FMPT), consists of 34 experiments — ranging from crystallizing superconducting materials to monitoring the health of NASDA's payload specialist. This complement of experiments allows the maximum number of Japanese scientists to participate in space-based research, gather data on mission operations, and demonstrate the effective use of the space environment for research. Spacelab J will also be the first time a NASDA astronaut has flown in space.

For NASA, nine experiments will expand knowledge of microgravity and life sciences gathered on previous Spacelab missions and will allow preparations for Space Station Freedom. Testing technology and procedures on this mission will serve as a precursor to Freedom's systems and also will demonstrate the cooperative working relationship developed with one of our Space Station partners.

Spacelab J

Microgravity and Life Sciences

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Mission Overview

Spacelab J is a joint venture between the National Aeronautics and Space Administration (NASA) and the National Space Development Agency of Japan (NASDA). Using a Spacelab pressurized long module, 43 experiments — 34 sponsored by NASDA and 9 sponsored by NASA — will be performed in the areas of microgravity and life sciences.


These experiments benefit from the microgravity environment available on an orbiting Shuttle. Here, removed from the effects of gravity, scientists will seek to observe processes and phenomena impossible to study on Earth, to develop new and more uniform mixtures, to study the effects of microgravity and the space environment on living organisms, and to explore the suitability of microgravity for certain types of research.

Orbital research appears to hold many advantages for microgravity science investigations, which on this mission include electronic materials, metals and alloys, glasses and ceramics, fluid dynamics and transport phenomena, and biotechnology. Gravity-induced effects such as sedimentation, hydrostatic pressure, and convection are reduced or eliminated in microgravity. This may allow the investigations on Spacelab J to help scientists develop a better understanding of how these gravity-induced phenomena affect both processing and products on Earth and to observe subtle phenomena that are masked in gravity. They may even be able to produce materials that are significantly different from, or even superior to, Earth-developed counterparts: purer, more homogenous, or more nearly perfect in internal structure. The data and samples from these investigations will not only allow scientists to better understand the materials involved but also will lead to improvements in the methods used in future experiments.

Life sciences research will collect data on human adaptation to the microgravity environment, investigate ways of assisting astronauts to readapt to normal gravity, explore the effects of microgravity and radiation on living organisms, and gather data on the fertilization

and development of organisms in the absence of gravity. This research will improve crew comfort and safety on future missions, while helping scientists to further understand the most complex machine on Earth — the human body.

NASDA began developing its portion of the Spacelab J payload, known as the First Materials Processing Test, in 1979 and contacted NASA in 1984 about the potential for a joint Shuttle mission. Since the experiments selected by the Japanese

did not fill the Spacelab module, NASA developed and manifested experiments to fill the module and complement the theme of the Spacelab J investigations. Further negotiations between the two space agencies, culminating in 1991, resulted in plans to share data and samples more widely between Japanese and U.S. investigators to maximize the science return. 



NASDA
宇宙開発事業団



National Aeronautics and
Space Administration

Mission operations are shared by the U. S. and Japan.

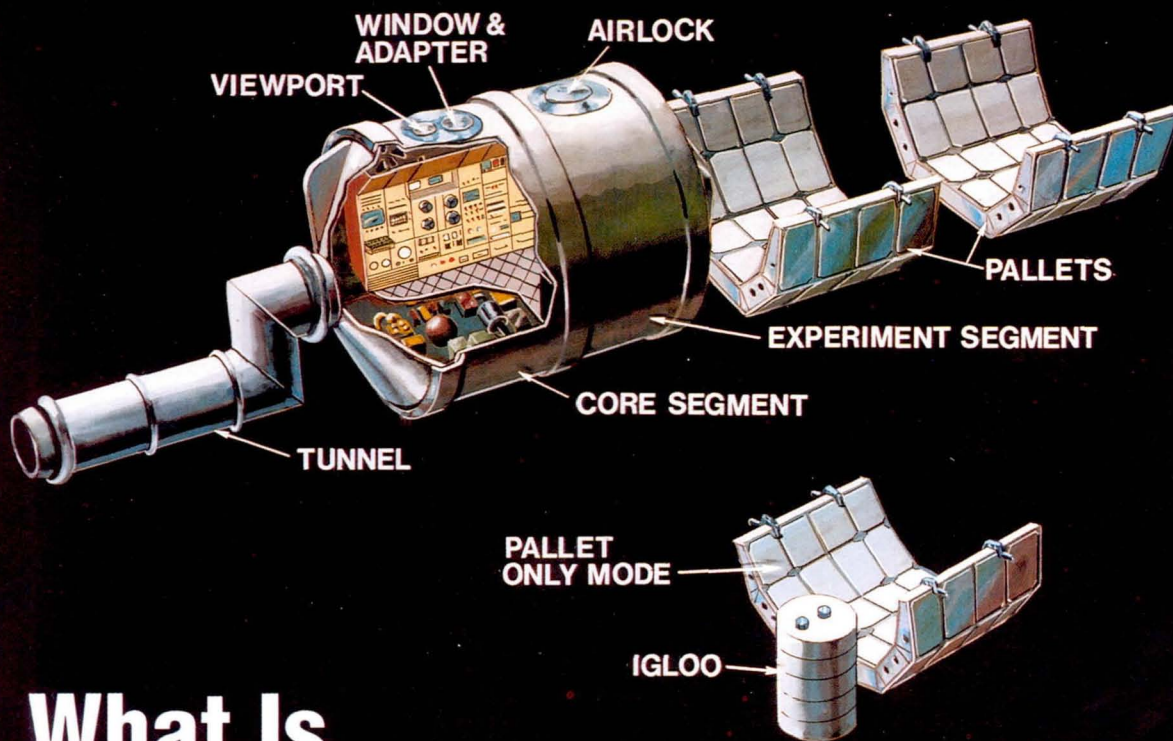
NASA provides payload integration, assembling the different investigation facilities and support hardware in the Spacelab module and ensuring that all systems work properly. NASA is also responsible for launch services; mission management, which includes mission oversight, payload integration, and crew training; and some postflight support. NASDA is responsible for supporting the selection of the Japanese experiments by the Space Activities Commission, overseeing experiment development, providing a payload specialist, and ensuring that the First Materials Processing Test equipment is ready for flight.

Mission operations responsibilities are shared by the U.S. and Japan. NASA is responsible for mission design and

on-orbit mission operations. NASDA provides science and engineering support at Spacelab Mission Operations Control during the mission.

Spacelab J is currently scheduled to be launched in the summer of 1992 from Kennedy Space Center to a 296-kilometer altitude orbit with a 57-degree inclination for a 7-day mission. The mission plan is ambitious: the timeline is crew-intensive, many experiments share essential equipment, and almost every kilowatt-hour of energy available during the mission will be used.

Careful planning, however, ensures a schedule that meets the needs of both the investigators and the crew. The investigations receive the maximum exposure to the microgravity environment, along with



What Is Spacelab?

A. A modular series of components including pallets and pressurized modules.

B. An extremely successful international partnership between NASA and the European Space Agency.

C. All of the above.

The correct answer, of course, is C. Spacelab is all of these things and more. It is a series of modular components that can be assembled into unique mission configurations for flight on the Space Shuttle. The components consist of laboratory sections, pallets, and associated hardware.

Pressurized Spacelab modules provide a shirt-sleeve environment for conducting research. These laboratories come in two basic configurations: long and short. The short module can be used for a small number of experiments or in conjunction with experiments mounted on pallets in the Shuttle payload bay. The long module is used for a large number of experiments. Both modules have similar basic equipment, such as a general-purpose workstation and master controls. They can also be outfitted with a variety of extra items, such as a scientific airlock, viewports, and other hardware needed by a particular mission.

For the Spacelab J mission, a long module holds eight double racks and four single racks of equipment. These racks contain all the furnaces, workstations, experiment facilities, storage compartments, and support equipment needed for a majority of the experiments. Some additional storage facilities and one experiment are located in the orbiter middeck. There is one viewport and no scientific airlock on the Spacelab J module.


Spacelab pallets are U-shaped platforms where instruments are mounted and can be exposed directly to the space environment. These instruments can then measure the environment around the Shuttle, conduct experiments that require exposure to vacuum conditions or plasma, or perform Earth and astronomical observations. To aid observations, the Spacelab system includes a three-axis pointing system for telescopes and other sensors. Spacelab J will not use any of this equipment.

The European Space Agency, a consortium of 14 European countries sponsoring space research and technology, was responsible for funding, developing, and constructing Spacelab. NASA is responsible for its launching and operational use. With the Spacelab J mission, this successful international partnership adds a new dimension, bringing together most of the partners for Space Station Freedom.

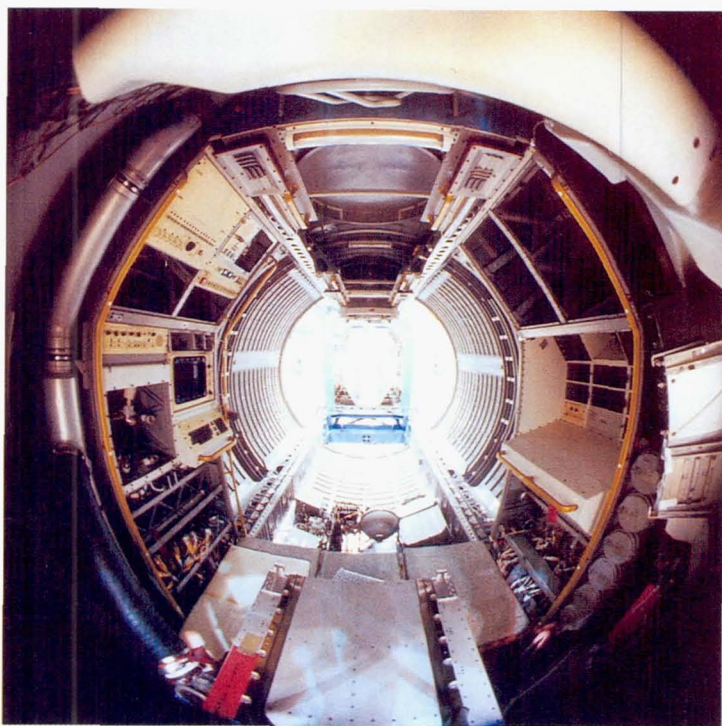
the necessary human control needed to perform them. The crew operates on a schedule that, while quite intense, allows them sufficient time for each operation.

After completing on-orbit operations, the crew stores specimens and data and secures the Spacelab module for landing. Certain samples requiring special treatment are removed as quickly as possible after landing. If the orbiter does not land at Kennedy Space Center, the remaining samples are removed when the orbiter is returned there.

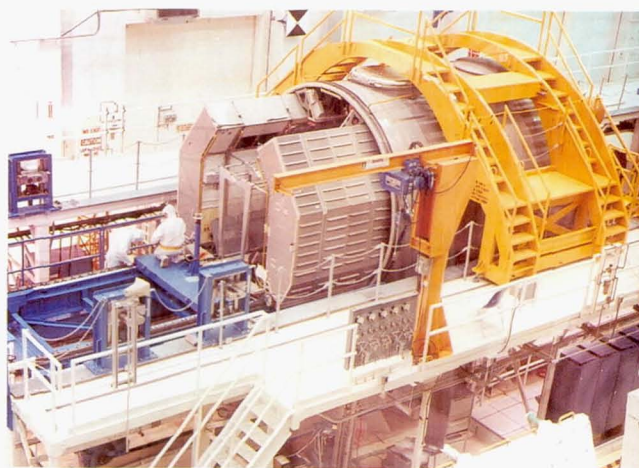
The Spacelab J mission also represents two crew "firsts." Although a Japanese journalist has flown aboard the Soviet Mir spacecraft, Spacelab J will carry the first NASDA astronaut into space. In addition to specific mission duties, NASDA's astronaut will help that agency develop the selection, training, and health maintenance procedures for an astronaut corps.

NASA will have its first science mission specialist. Under new NASA guidelines for missions requiring a payload specialist not provided by the customer, NASA selects a mission specialist to fill those duties. Payload specialists are persons trained to perform specific science duties on a particular mission, while mission specialists are career NASA astronauts trained to operate experiments and standard orbiter and Spacelab hardware. Since the chosen NASA astronaut will be performing payload specialist duties and is a trained mission specialist, the term science mission specialist has been developed. 

**Spacelab
Modular
Components —
Spacelab
hardware
can be
combined
to meet
the needs
of any
mission.**



A fish-eye lens provides this "insider's" view of rack integration.



The modular design of Spacelab extends to its equipment racks. Racks, similar to those on Spacelab J, are being loaded into a Spacelab module during the final stages of integration.

Mission Development



Dr. Mamoru Mohri, Dr. Chiaki Mukai, and Dr. Takao Doi were selected from more than 500 candidates to train for the Spacelab J mission as Payload Specialist Candidates.

Preparations for Spacelab J began in August 1979 with the development of the concept of the First Materials Processing Test. It was then that NASDA, after examining the potential of microgravity research and learning of the opportunity to conduct research aboard the Space Shuttle/Spacelab, issued an Announcement of Opportunity for experiments in microgravity science and life sciences.

NASDA received 103 proposals from the Japanese scientific community and in March 1980 selected 62 investigations for initial consideration. After evaluating the proposals and combining some investigations, the agency selected 34 experiments whose principal investigators were named in July 1984.

An announcement was also made for astronaut candidates, from whom one person would be chosen as the payload specialist for the Spacelab J Mission. NASDA reviewed applications from 533 individuals for the position and selected Dr. Mamoru Mohri, Dr. Chiaki Mukai, and Dr. Takao Doi as the candidates. Each trained as a payload specialist candidate for the mission, and in April 1990, Dr. Mohri was named to fly on Spacelab J. Dr. Mukai and Dr. Doi will serve as backups for Dr. Mohri and, during the mission, will work in Spacelab Mission Operations at Marshall Space Flight Center.

NASDA contacted NASA in January 1984 about flying the First Materials Processing Test, and a Launch Services Agreement between the agencies was signed on March 31, 1985, for the

Spacelab J mission. Under this agreement, NASDA selects and develops its payload for the Spacelab module, while NASA provides launch services and mission management on a reimbursable basis. In addition, to use the module's capabilities fully, NASA develops and manifests experiments compatible with the FMPT theme of materials processing and life sciences.

The experiments for the NASA portion were selected as the result of Announcements of Opportunity, Dear Colleague Letters, and other solicitations sent to scientists across the country. The principal investigators for the NASA experiments joined with their Japanese colleagues to form the Spacelab J Investigator Working Group.

The Investigator Working Group consists of the principal investigators for each experiment and the mission scientist who chairs the group. It meets periodically before the mission to coordinate activities and planning

between the investigators, to develop the qualifications for and recommend the payload specialist(s), and to advise the mission management team on issues related to science operations. During the mission, the Investigator Working Group becomes the Science Operations Planning Group and meets to consider mission developments and, if necessary, suggests revisions to operations and the timeline to obtain the maximum scientific return for Spacelab J.

The experiments on Spacelab J not only have passed a rigorous selection process but have also met numerous safety and technical requirements. The Spacelab J team has reviewed each experiment for potential hazards and has taken steps to reduce or eliminate those that were identified. Experiment hardware has been tested for both safety and reliability, while specially designed containers virtually eliminate the possibility of any sample material being released into the Spacelab environment.

Human experiments also have met exacting standards designed to

ensure subject safety and comfort. Those experiments involving non-human vertebrates, such as the frogs and carp being studied on Spacelab J, must meet similar guidelines, as well as equally strict rules of animal care and use.

NASA Spacelab J administration operates under the Program Manager, who administers all activities including fiscal management and the development of program goals and objectives.

The Program Manager also assures that mission requirements are understood, approved, and budgeted. Program Managers in the Microgravity and Life Sciences Divisions perform similar duties for specific items of hardware. When a mission contains both Microgravity Science and Life Sciences research, a Mission Program Scientist is selected from one division and is supported by a Program Scientist from the other. The Mission Program

NASDA selects and develops its payload for the Spacelab module, while NASA provides launch services and mission management.



The Spacelab J IWG oversees and directs the development of mission science objectives. During the mission, the IWG meets to review developments and suggest changes to maximize the scientific return of the mission.

Scientist establishes mission science objectives and oversees science development, including publication of scientific results. The Mission Manager is responsible for implementing Spacelab J by managing mission resources, design and development, payload integration, crew training, and associated scheduling. The Mission Scientist ensures the maximum scientific yield for the mission by working with the investigators to establish science requirements and priorities and by serving as the interface between the principal investigators and the Mission Manager. The Chief Engineer organizes, plans, and directs the technical work necessary to bring flight-ready hardware together and integrate it into a complete package.

The development and management of Spacelab J

encompasses more than this apparently simple structure. A variety of NASA centers, such as the Ames Research Center (California), Dryden Flight Research Facility (California), Goddard Space Flight Center (Maryland), Kennedy Space Center (Florida), Johnson Space Center (Texas), Lewis Research Center (Ohio), and Marshall Space Flight Center (Alabama) have been involved in experiment development, operational support, payload integration, and Shuttle operations.

Within the Japanese government, NASDA operates under the Science and Technology Agency, the Ministry of Posts and Telecommunications, and the Ministry of Transport. The First Materials Processing Test mission operates under an Executive Director, a Space Experiment Group Director, a Project Manager, and a Project Scientist. 

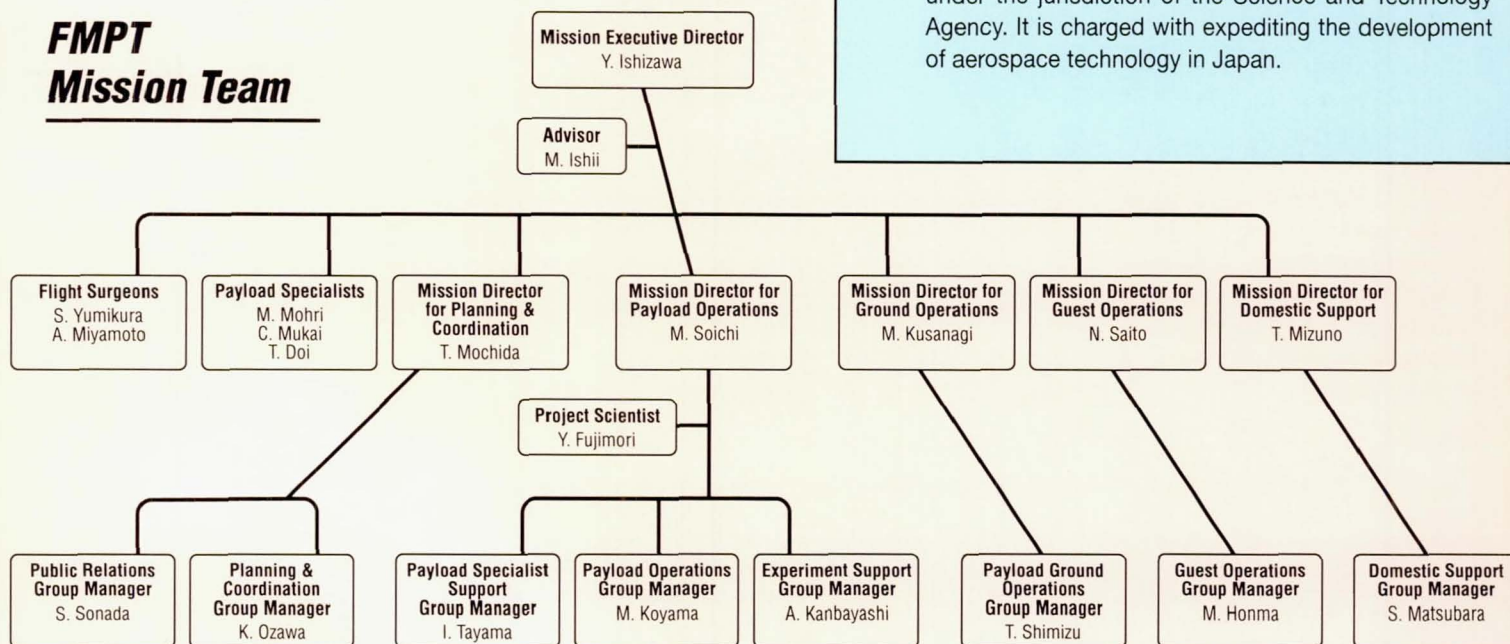
Japan's Space Organizations

NASA is organized as an independent government agency; NASDA comes under the jurisdiction of three separate Japanese government organizations: the Ministry of Posts and Telecommunications, the Ministry of Transport, and the Science and Technology Agency. Just as NASA is part of the executive branch of the U.S. government, NASDA, through its parent ministries, comes under the jurisdiction of the Prime Minister.

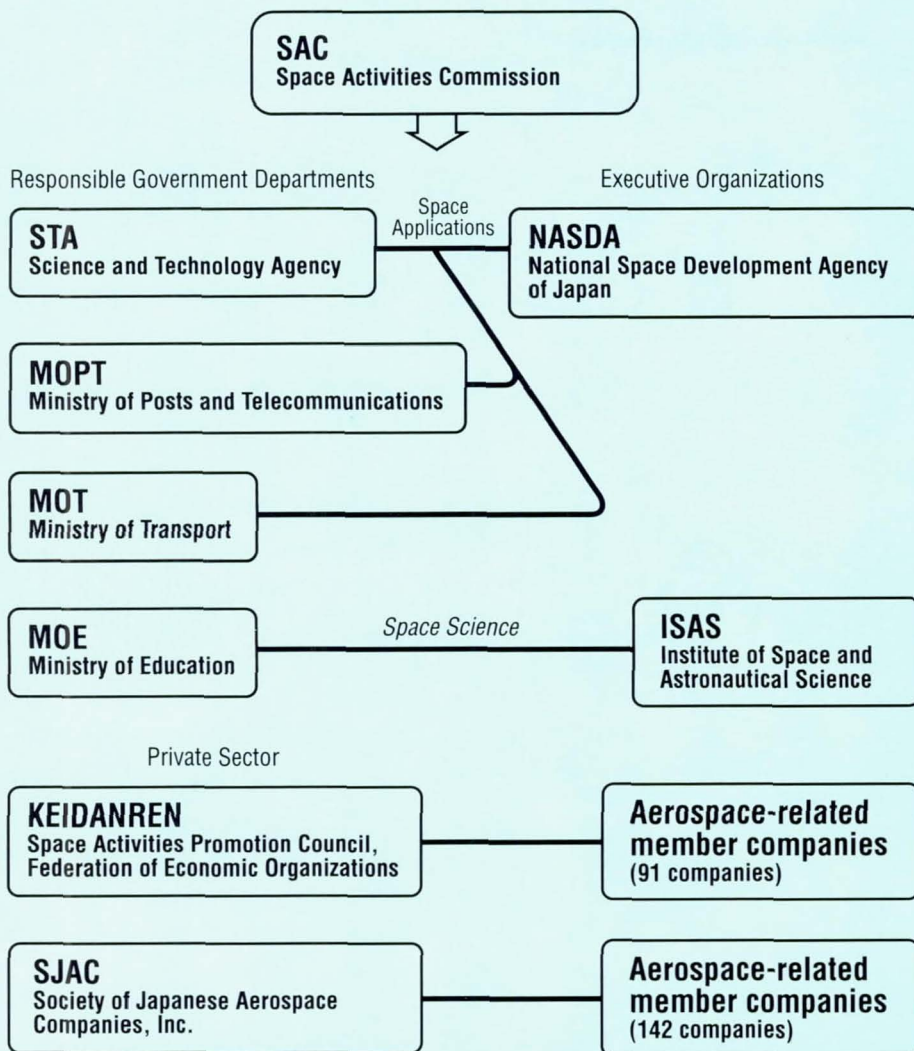
Within the Prime Minister's office is the Space Activities Commission. This organization is composed of five eminent individuals and includes the Minister of State for Science and Technology, who serves as the Space Activities Commission Chairman. The other four members are nominated by the Prime Minister and approved by the Diet, the Japanese parliament. As one of its duties, the Space Activities Commission sets space policy and recommends budgets for the major organizations involved with space exploration and utilization. For Spacelab J, the commission was responsible for selecting the experiments that make up the First Materials Processing Test.

While NASDA is the largest space development agency in Japan, there are other governmental departments involved with space. The first is the Institute of Space and Astronautical Science (ISAS), which is an intra-university research institute under the jurisdiction of the Ministry of Education. ISAS is responsible for space science research conducted on balloons, sounding rockets, and light-lift launch vehicles; developing these vehicles and the scientific payloads and satellites carried on them; launching them; and collecting data. The second is the National Aerospace Laboratory, which is under the jurisdiction of the Science and Technology Agency. It is charged with expediting the development of aerospace technology in Japan.

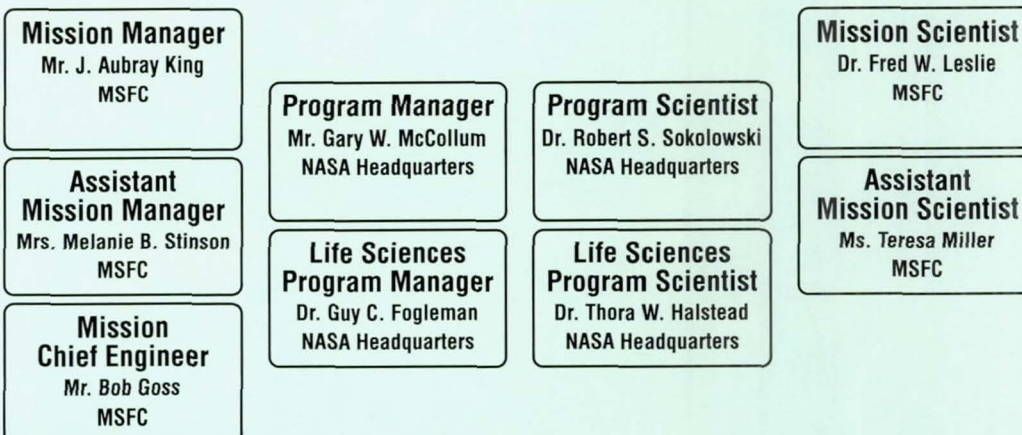
FMPT Mission Team



Space-Related Organizations in Japan and NASDA's Role



SL-J Management Team



Spacelab J will perform research in both microgravity and life sciences with 43 investigations: 27 will study microgravity sciences and 16 will explore the life sciences. The experiment number issued to each Japanese experiment by NASDA is listed in parentheses at the end of the experiment title.

Microgravity Sciences

The Spacelab J microgravity sciences experiments explore five major areas — electronic materials, metals and alloys, glasses and ceramics, fluid dynamics and transport phenomena, and biotechnology. New materials to be investigated include a variety of advanced materials, such as amorphous semiconductors, lightweight composites, and superconducting compounds. Studies on deoxidation, gas evaporation, sintering, and other areas are expected to yield information useful to the understanding of typical materials processing technologies on Earth. A technology experiment will provide data to support these investigations.

The Crystalline State

Everyday life brings us in contact with a number of different material forms, such as solids and fluids. Just as fluids can be subdivided into liquids and gases, solids can be subdivided into crystalline or non-crystalline (amorphous) forms based on the internal arrangement of their atoms or molecules.

The most common form of solids is crystalline. Examples are minerals, such as geodes or quartz crystals; metals, such as steel, iron, or lead; ceramics, such as a dinner plate or floor tile; and semiconductors, such as the ones in televisions or radios. Crystalline solids have a long range, three-dimensional order to their internal structure: the atoms line up on planes that are stacked upon each other. Non-crystalline solids, such as plastics, glasses, and wood, have only a local order to their atoms.

Crystals typically have different regions, where the planes are lined up in different directions. This is known as a polycrystalline structure, and the individual elements are known as grains. The size and orientation of these grains help determine the strength of a metal or the brittleness of a ceramic. Some materials, such as semiconductors, can benefit from the elimination of all grains but one, producing a single crystal with the constituent atoms lining up on a single set of geometric planes.

Crystals can form in many ways: they can result from freezing liquids, the way ice cubes form; they can precipitate from solution, the way rock candy is made from a sugar solution; and they can condense from vapor, the way frost forms in a freezer. In all of these cases, gravity affects how the crystals grow. By conducting experiments on crystal growth in microgravity, scientists can learn how gravity influences this process and how crystals grown in microgravity differ from those grown on Earth.



The Fluid State

Everyone has practical experience with fluids — liquids and gases — and we know intuitively how a fluid will behave under “normal” circumstances. Steam rises from the surface of a hot spring or a boiling pot, and water spilled on a tabletop runs over, and even off, the surface. Gravity is intimately involved with many of the aspects of fluid behavior we are accustomed to on Earth.

Many of our intuitive expectations do not hold up in microgravity, however, because other forces, such as surface tension, control fluid behavior. A familiar example are the spherical drops of liquid created when the astronauts have “spilled” water to show audiences what happens. Surface tension causes drops of any liquid to form almost-perfect spheres. On Earth, gravity distorts the shape; a perfect example of such surface-tension distortion is the teardrop shape of a bead of water. Less visible, however, is the need to pressurize tanks containing fluids, such as propellant tanks, so that the fluids will flow from the tank and through the pipes. While these differences in fluid behavior often present engineers and astronauts with practical problems, they also offer scientists unique opportunities to explore different aspects of the physics of fluids.

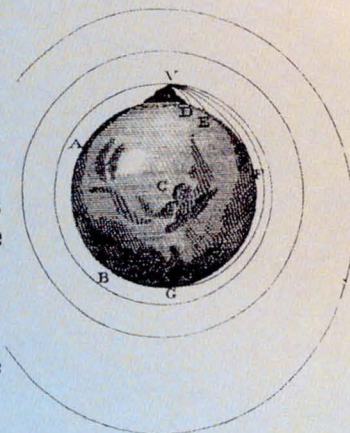
The knowledge of fluid behavior gained in space is not only important to basic science but is also the key to new technologies. The behavior of fluids is at the heart of many phenomena in materials processing, biotechnology, and combustion science. Surface-tension-driven flows, for example, affect semiconductor crystal growth, welding, and the spread of flames on liquids. The dynamics of liquid drops are an important aspect of chemical process technologies and in meteorology. Research conducted in microgravity, such as that being conducted on Spacelab J, will increase our understanding of fluid physics and provide a foundation for predicting, controlling, and improving a vast range of technological processes.



Microgravity in Gravity

Many people do not realize that Earth's gravitational field extends far out into space, in fact far beyond the orbit of the Space Shuttle. If it were possible to build a tower reaching to the height of the Shuttle's orbit, gravity would be almost as strong at the top of the tower as it is on the ground. A person stepping off this tower would drop to the ground, just as he or she would from a tall skyscraper. But if this is true, why do Shuttle crewmembers float and a microgravity environment exist for experiments?

Sir Isaac Newton hypothesized how an artificial satellite could be made to orbit Earth. He envisioned a very tall mountain extending above Earth's atmosphere so that friction with the air would not be a factor. He then imagined a cannon at the top of that mountain that fired cannonballs parallel to the ground. As each cannonball was fired, it was acted on by two forces. One force, the explosion of the black powder, propelled the cannonball straight outward. If no other force were to act on the cannonball, the shot would travel in a straight line and at a constant velocity. But Newton knew that a second force would act on the cannonball. Gravity would act to pull the cannonball down toward Earth. Because of the presence of gravity, the path the cannonball would travel would be bent into an arc ending at Earth's surface.



Newton's thought experiment demonstrated how additional cannonballs would travel farther from the mountain if the cannon were loaded with more black powder each time it was fired. With each shot, the path would lengthen and soon, cannonballs were disappearing over the horizon. Eventually, a cannonball was fired with enough energy, in Newton's imagination, that it fell entirely around Earth and came back to its starting point. Provided that nothing would interfere with the cannonball's motion, it would continue circling Earth: it was in orbit.

This is how the Space Shuttle stays in orbit above Earth. It is launched in a trajectory that arcs above Earth so that the orbiter is travelling at just the precise speed to keep it falling while maintaining a constant altitude above the surface. For example, if the Shuttle climbs to a 320-kilometer-high orbit, it must travel at a speed of about 27,740 kilometers per hour to achieve and maintain orbit. At that speed and altitude, the Shuttle's falling path will be parallel to the curvature of Earth. Because the Space Shuttle is freefalling around Earth and the friction with the upper atmosphere is extremely low, a microgravity environment is established.

Why Process Materials in Microgravity?

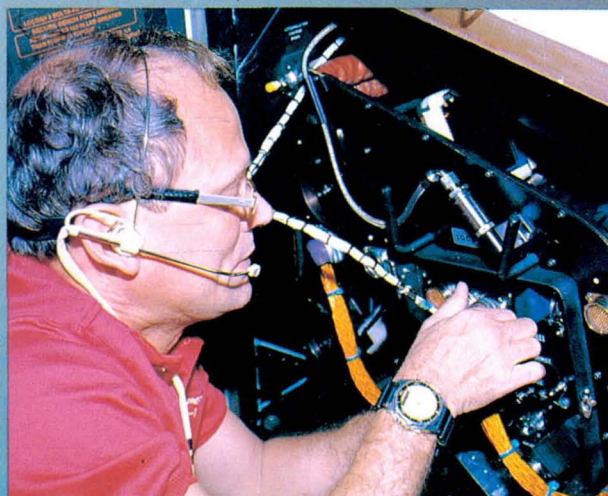
Gravity is such an accepted part of our lives that few people consciously consider it, though it affects everything we do. If we drop something, it falls to the floor; cold, dense air settles to the bottom of a room, while warmer, less dense air rises; dirt particles and lint eventually fall from the air to create dust on our shelves; and a liquid pours in a graceful arc from a container into a glass because of gravity's steady pull.

Manufacturing processes take into account the pervasiveness of gravity. Whenever possible they take advantage of it. For example, during the processing of many metals, waste (called slag) is allowed to rise to the top so it can be skimmed off. However, it is not always desirable to have the effects caused by gravity: products may not be uniformly mixed, the internal structure and composition may not be as ordered as could be, and other non-desirable traits may exist.

Microgravity appears to reduce or eliminate sedimentation (the settling and separation of heavier elements/objects from lighter), convection [flows within fluids (liquids or gases) caused by temperature differences], and other behaviors caused by gravity. Conducting research in microgravity can provide a two-fold advantage for scientists. First, they can explore the science of processing by studying events and phenomena normally masked by gravity. Second, they can try to create new or improved materials.

This basic research will help scientists better understand materials, materials processing, and the potential the microgravity environment offers for research and production. Ultimately, this research may result in improvements to production methods and materials on Earth. However, we can no more guess at what these advances will be than people 20 years ago could have foreseen portable compact disc players or tires belted with material lighter and stronger than steel.

The investigations conducted on Spacelab J will provide scientists with data on a variety of materials and processes. Using this as a foundation, scientists will be able to improve investigations and equipment so the full benefit of the microgravity environment can be realized.



Growth Experiment of Narrow Band-Gap Semiconductor Pb-Sn-Te Single Crystals in Space

Dr. Tomoaki Yamada, Principal Investigator
Nippon Telegraph and Telephone Corporation (M-1, NASDA)

Pb-Sn-Te (lead-tin-tellurium) semiconductor material is used widely in electronic applications requiring infrared sensitivity because it can detect a broad range of infrared radiation frequencies. This sensitivity allows it to be used in products ranging from fire and security systems to space-based imaging systems.

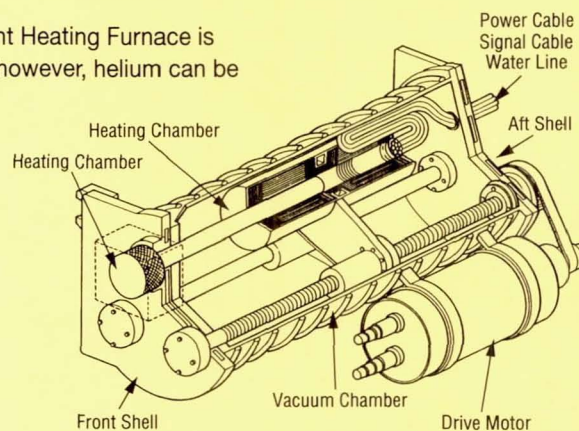
This experiment attempts to produce homogeneous crystalline ingots of Pb-Sn-Te using the Gradient Heating Furnace. A Pb-Sn-Te seed and its polycrystalline ingot are placed inside a boron nitride crucible equipped with a plunger made from the same material. This crucible is sealed in two quartz ampoules and a tantalum cartridge for safety. To eliminate a free liquid surface and attendant surface-tension-driven convection (Marangoni convection), the boron nitride plunger, powered by a graphite spring, pushes the melted material against the sides of the crucible. The cartridge is placed in the furnace where a special heating element, 985 degrees Centigrade (°C) at one end and 565 °C at the other, moves over the sample. This establishes a temperature gradient of 40 °C per centimeter (cm), which moves at a rate of 0.55 cm per hour over the sample, allowing the crystal to grow directionally. The ingots produced are examined after the flight.

Gradient Heating Furnace

The Gradient Heating Furnace facilitates investigation of crystal formation, eutectics, and solidification of semiconductors, ceramics, and alloys. It is a moving furnace with three temperature zones, allowing a temperature gradient to be moved over the length of the sample.

As seen in the diagram, a motor-driven screw moves the heating unit over the sample cartridge for precise control. The forward part of the unit is the high-heat zone, which can reach a maximum temperature of 1,100 °C. The middle portion is the gradient, or cooling section, while the rear portion is the low-heat zone. The cooling section uses a fluid loop for heat transfer.

Processing in the Gradient Heating Furnace is conducted in a vacuum; however, helium can be flushed through the unit for rapid cooling.



An interior view of the Gradient Heating Furnace

The Travelling-Zone Method of Crystal Growth

The travelling-zone method can be used with certain compounds to provide less strain on the structure of the crystal being produced than many other methods. This is possible because of an interesting chemical principle.

If you were to mix equal numbers of atoms of certain materials together, a compound would be formed that has a melting temperature higher than for other combinations of the two materials. If you were to add more of one of the materials, the melting point for the compound would be less than it was for the equal mixture.

The travelling-zone method makes use of this by having an excess amount of one component of the compound at one end of the sample. In the case of lead-tin-tellurium (Pb-Sn-Te), excess tellurium might be added. This portion of the sample will melt at a lower temperature than the actual desired compound. As the melt is moved across the sample, the excess component moves with it. Since the maximum processing temperature is lower than that required for melting the desired compound, there is less thermal stress on the structure of the crystal formed.

The Float-Zone Method of Crystal Growth

The float-zone method of crystal production uses a rod of seed material and a rod of raw material. The two rods are joined end-to-end in a furnace (see figure 1) and heated. A melt is established at the joint (see figure 2) and moved into the raw material as desired to produce a crystal or crystals. The crystal is then separated from the raw material for analysis.

On Earth, gravity distorts the melt, or molten zone of material (see figures 3 and 4). Rotating the sample will reduce this distortion but the problem cannot be completely eliminated. Microgravity appears to offer a solution to the distortion and heat distribution problems and may allow significant improvement in the crystals produced. With the knowledge developed from Spacelab J and other missions, scientists may find a way to address the challenge of Marangoni convection in the melt zone, allowing the benefits of using this method in microgravity to be fully realized.



Fig. 1



Fig. 3



Fig. 2

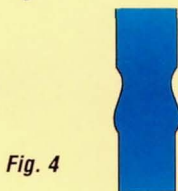


Fig. 4

Growth of Pb-Sn-Te Single Crystal by Travelling-Zone Method in Low Gravity

Dr. Yusaburo Segawa, Principal Investigator
Institute of Physical and Chemical Research (M-2, NASDA)

The production of single Pb-Sn-Te crystals is also the subject of this investigation, but a combination of the float-zone and travelling-zone methods is used in the Image Furnace. This experiment allows scientists to study the fundamental mechanism of crystal growth and possibly to propose a new method of crystal growth.

On Earth, sedimentation and other factors make the growth of a single homogeneous crystal extremely difficult, limiting studies of the crystal growth process. In microgravity, sedimentation and many other gravity-driven phenomena are reduced or eliminated. By processing on Spacelab J and encapsulating the sample in a quartz ampoule (a material to which the molten sample will not adhere) to eliminate the crystal deformities caused by adhesion, researchers hope to obtain well-grown crystals for study.

The procedures for the experiment are simpler than those of a typical travelling-zone method. First, the encapsulated sample of Pb-Sn-Te material is placed on the end of the Image Furnace lower shaft. Second, a melt zone is established as the crewmember adjusts the power of the lamp. Third, once the proper melt has been established, the Image Furnace automatically controls experiment procedures. The resultant crystal(s) will be examined on Earth to determine the effectiveness of this production method and to study the mechanisms of the crystal growth.

Growth of Semiconductor Compound Single Crystal by Floating Zone Method

Dr. Isao Nakatani, Principal Investigator
National Research Institute for Metals (M-3, NASDA)

This investigation uses the float-zone method in the Image Furnace to grow a large-size single crystal of In-Sb (indium antimonide), which has high density and low surface tension in the molten state. The purpose of this experiment is to investigate the properties of In-Sb crystals grown in space and to verify both the feasibility and the usefulness of the float-zone method for producing high-density, low-surface-tension crystals in microgravity.

The experiment begins when a crewmember places the rod-like samples in the Image Furnace; the lower rod is a single crystal, while the upper rod is a polycrystalline sample. Once melting is established at the ends of both samples, the ends are joined, the melt moved back into the single crystal, and then into the polycrystal. Float-zone growth then takes place over the sample, and the rods are pulled apart at the end of the growth process. The resulting samples are studied on Earth after the flight.

Growth of Silicon Spherical Crystals and Surface Oxidation

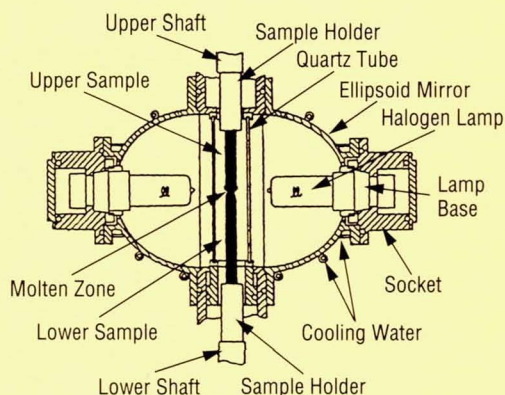
Dr. Tatau Nishinaga, Principal Investigator
University of Tokyo (M-9, NASDA)

This experiment will attempt to produce spherical and hemispherical single crystals of silicon to study its growth behavior, electronic properties, and surface oxidation. Studies of these two crystals will give scientists a better understanding of the most important semiconductor substrate material.

Although the shape of the crystals produced will be, on the average, spherical, detailed study of the crystals is expected to reveal anisotropy. The properties of an anisotropic material differ depending on the direction in which the property is measured. Researchers are interested in studying the growth, the impurity doping, and oxidation anisotropies of the silicon crystals to better understand the mechanisms that cause them.

To produce one crystal, a sphere of silicon is placed in the Crystal Growth Experiment Facility. There, the silicon is melted and grows into a single crystal, which is cooled and stored for study after the Shuttle returns. The second crystal is also grown in a similar facility using a rod of silicon material, which is melted from one end. Marangoni-type flows in the molten silicon are eliminated because of the near-isothermal (almost constant temperature) heating. Barring flows created by other sources such as orbiter movements or vibrations from equipment or activities, the experiment should result in a uniform distribution of an impurity that has been deliberately added to the samples. Such a deliberately added impurity is known as a dopant. Because the second crystal will not touch the sides of the furnace during growth, contact contamination is eliminated. The spherical shape of the melts is the natural result of surface tension combined with the microgravity environment.

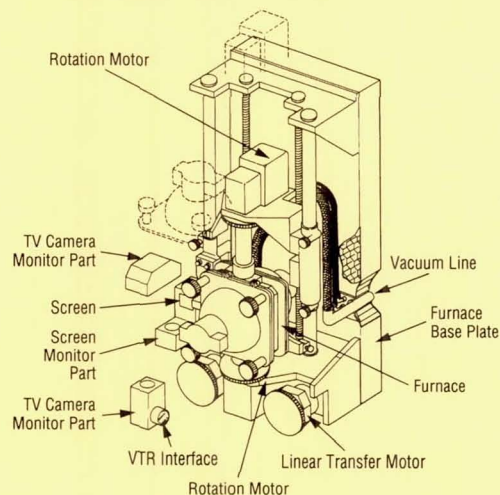
Image Furnace



An interior view of the furnace section of the Image Furnace shows the placement of samples and the halogen lamps that provide precise heating for the furnace.

The two components together so that they meet in the center of the furnace section. The furnace is activated and a melt zone established; this zone can be varied by moving the furnace section. At the end of operations, the payload specialist can separate the rods and remove the crystal. Video of each experiment is simultaneously recorded and downlinked to the ground for the principal investigator.

This view of the entire Image Furnace shows the placement of the furnace section in relation to the other components.



The Image Furnace supports experiments in crystal growth that use the float-zone method. Two halogen lamps and twin ellipsoidal mirrors sharing a common focus make up the furnace section of the unit. This section can be moved up or down the sample as needed to control melting and crystal growth.

Operations begin when a payload specialist loads the upper shaft of the unit with raw material and places crystal seed material into the lower shaft. The shafts move

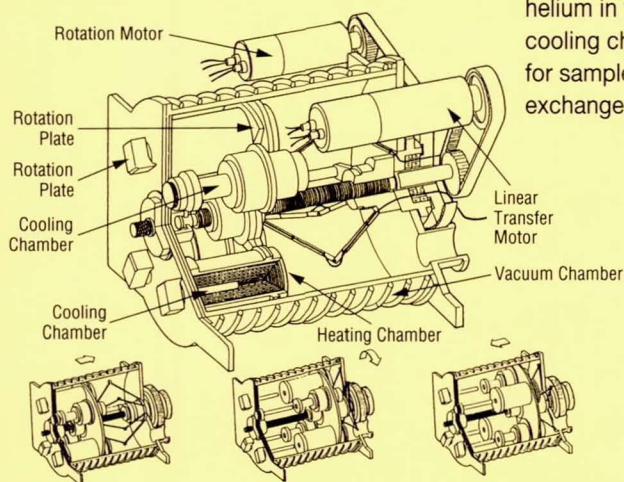
Continuous Heating Furnace

The Continuous Heating Furnace provides high temperature (up to 1,300 °C) and rapid cooling to two sets of samples concurrently.

Two heating and two cooling chambers are mounted on a worm drive inside the unit. After samples have been inserted, the heating units are activated, and the materials in the sample are processed. The chambers are then pulled back, rotated 90 degrees, and pushed forward again. The two heated samples are then covered by the cooling chambers, and two new samples are placed in the heating chamber. Sample exchange takes place after the cooling phase and before the units are pulled back and rotated.

Heating occurs in vacuum conditions only, while cooling is accomplished through a water jacket on the cooling chamber and helium gas. Gas approximating normal Spacelab air replaces

helium in the cooling chamber for sample exchange.



An interior view of the Continuous Heating Furnace. The smaller drawings show how the furnace rotates the heating and cooling chambers over the samples.

Fabrication of Si-As-Te:Ni Ternary Amorphous Semiconductor in Microgravity Environment

Dr. Yoshihiro Hamakawa, Principal Investigator
Osaka University (M-13, NASDA)

The semiconductor material Si-As-Te:Ni (silicon-arsenic-tellurium:nickel) is of interest from both research and technological applications standpoints. It is considered to be an excellent system for investigating the compositional dependence of atomic and electronic properties in the random network of solids because its energy gap can be controlled in a range from 0.6 electron volts (eV) to 2.5 eV. From the technological standpoint, it can be used in superlattice and opto-electronic devices. However, it has been difficult to produce because of the large differences in the densities, melting points, and vapor pressures of the individual elements. Microgravity may offer solutions to some or all of these problems.

In this experiment, several samples of Si-As-Te, mixed with nickel so the electron valence controllability can be examined, are placed in the Continuous Heating Furnace and heated to 1,300 °C. After being heated at this temperature for 1 hour, the samples are quenched, or rapidly cooled, in a special cooling chamber using helium. In less than 10 minutes, they cool from 1,300 to 45 °C. After the mission, scientists study the structure and electronic properties of the materials.

Crystal Growth of Compound Semiconductors in a Low-Gravity Environment

Dr. Masami Tatsumi, Principal Investigator
Sumitomo Electric Industries, Ltd. (M-22, NASDA)

On Earth, concentration gradients and/or temperature gradients in molten materials can generate convective flows that adversely affect the growth of semiconductor crystals. In microgravity, however, convective flows are expected to be reduced so that crystal growth occurs in an environment controlled by diffusion. Diffusion is the mixing of two or more substances because of the random motions of their component atoms, ions, and molecules. This experiment will examine the diffusion growth of crystals and the impact this method has on the microscopic characteristics and macroscopic properties of bulk grown In-Ga-As (indium-gallium-arsenic) semiconductor crystals.

A polycrystalline sample of In-Ga-As, pressed by a spring to prevent Marangoni convection, is heated in the Gradient Heating Furnace. In the high-heat zone, the temperature is 1,070 °C, while the lower zone is 600 °C. The temperature changes 60 °C per cm between these two zones, and crystal growth is obtained by moving this temperature profile over the sample at a rate of 0.4 centimeters per hour for approximately 7.5 hours. The bulk crystals produced on the mission are compared with crystals produced by the same method on Earth, so the effects of microgravity on crystal growth and properties can be determined.

Casting of Superconducting Filamentary Composite Materials

Dr. Kazumasa Togano, Principal Investigator
National Research Institute for Metals (M-4, NASDA)

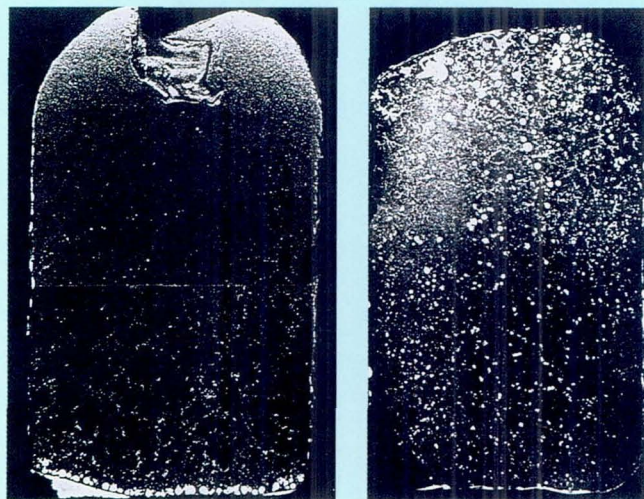
The progress made in superconductors in the last few years has propelled these materials from the laboratory toward everyday use. No longer confined to supercold experiment chambers, researchers are creating superconducting materials that can work at higher and higher temperatures — possibly even at “room” temperature one day.

This experiment investigates two series of new superconducting compounds. The first series is composed of aluminum, lead, and bismuth. The second consists of silver and copper; silver, yttrium, barium, and copper; and silver, ytterbium, barium, and copper. Both series are expected to have almost no electrical resistance at the temperature of liquid nitrogen, approximately -195°C .

Scientists want to produce these superconducting compounds in microgravity for the same reason they are producing semiconductor compounds: to obtain improved conductivity resulting from more uniform crystal growth. Just as a perfect lattice structure in a semiconductor increases its conductivity, so it does in a superconductor. The alloys produced in this experiment will be formed into wire on Earth for resistance testing at various temperatures.

Three samples of each compound are heated in the Continuous Heating Furnace at $1,300^{\circ}\text{C}$ for 17 minutes. The samples cool in vacuum for 1 minute and then are cooled to room temperature using helium. The Continuous Heating Furnace is used because two samples can be cooled while two others are heated, allowing the 12 experiment samples to be processed efficiently. Each sample is in a boron nitride container that is triply encapsulated in tantalum cartridges for safety.

A preliminary test of the first series (aluminum, lead, and bismuth) was conducted on a German TEXUS 13 sounding rocket. The sample had been preheated to $1,200^{\circ}\text{C}$ before flight and was allowed to solidify in microgravity. This sample showed a much more homogeneous distribution of the lead and bismuth in the aluminum, although a small difference in size distribution apparently resulted from the presence of a temperature gradient.

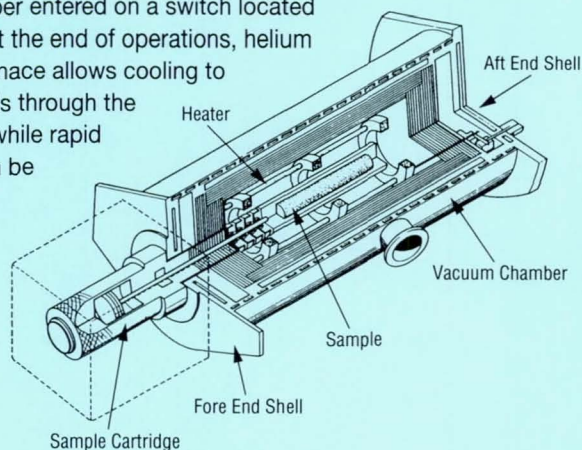


The more homogeneous distribution of particles in microgravity is evident when comparing samples of Al-Pb-Bi processed under normal gravity (left) and microgravity (right).

The Large Isothermal Furnace

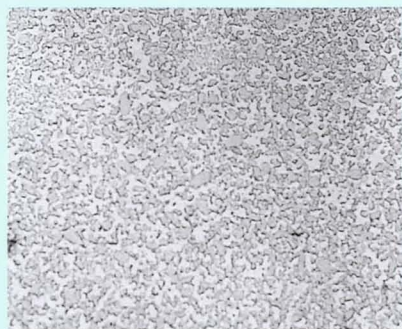
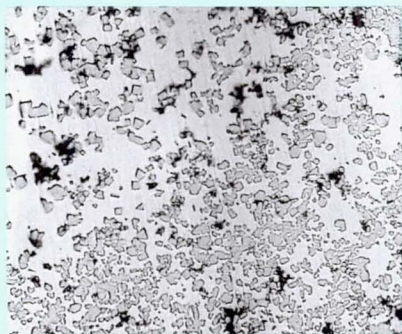
The Large Isothermal Furnace is a vacuum-heating furnace designed to uniformly heat large samples. It has a maximum temperature of 1,600 °C and can rapidly cool a sample through the use of a helium purge.

The furnace consists of a sample container and heating element, surrounded by a vacuum chamber. A crewmember inserts a sample cartridge into the furnace and locks it in place. The furnace is activated and operations are automatically controlled by a computer in response to an experiment number entered on a switch located on the control panel. At the end of operations, helium discharged into the furnace allows cooling to start. Furnace cooling is through the use of a water jacket, while rapid cooling of samples can be accomplished through a continuous flow of helium, in addition to the water jacket.



An interior view of the Large Isothermal Furnace

Microphotographs show the difference in particle dispersion between gravity processing (top) and processing under microgravity (bottom).



Formation Mechanism of Deoxidation Products in Iron Ingot Deoxidized with Two or Three Elements

Dr. Akira Fukuzawa, Principal Investigator
National Research Institute for Metals (M-5, NASDA)

Deoxidation products play an important role in the production of iron and iron alloys by bonding with oxygen and removing it from the metal. This experiment examines the structure and form (morphology), composition, and distribution of deoxidation products in iron and iron-nickel alloys that have had silicon, manganese, aluminum, and mixtures of the three added for deoxidation. Samples are processed in the Large Isothermal Furnace, and the finished products are examined on the ground.

Investigators hope to observe how these deoxidizers behave, form by-products, and affect the structure of the deoxidized iron and alloys in the absence of convection and buoyancy effects.

Preparation of Nickel Base Dispersion Strengthened Alloys

Dr. Yuji Muramatsu, Principal Investigator
National Research Institute for Metals
(M-6, NASDA)

Particle dispersion alloys, which are created by evenly distributing a powder of one metal in another, can offer significant advantages in terms of strength and durability. However, gravity limits or prevents the use of conventional melting processes. The particles do not disperse evenly because of the different specific gravities of the particles and the metal in which they are placed. Most particle dispersion alloys, therefore, are produced by the powder metallurgical process — which is complicated, expensive, limits the particle concentration to just a few percent of the total mass, and is difficult to use in the fabrication of large products.

The conditions available in the microgravity environment may allow particle dispersion alloys to be produced using conventional melting. This experiment processes samples of nickel-molybdenum, with particles of titanium carbide added, in the Large Isothermal Furnace. By examining the resulting samples, scientists can determine the effectiveness of processing such alloys in microgravity, the properties of the alloys produced, and the influence of other factors on the dispersion of the particles.

Diffusion in Liquid State and Solidification of Binary System

Dr. Takehiro Dan, Principal Investigator
National Research Institute for Metals (M-7, NASDA)

In microgravity, movement within liquid metals, resulting from differences in density and thermal convection, is reduced, leaving only the diffusion of constituent atoms. This experiment seeks to determine precisely this diffusion in a two-element sample, to understand the mechanism that controls this diffusion, and to expand the knowledge of the structure of liquid metals.

To do this, rods of silver and gold are joined together at one end with a hot press and placed in graphite crucibles. The crucibles are enclosed in two silica ampoules and a tantalum cartridge for safety. These previously prepared samples are heated in the Continuous Heating Furnace and cooled at two different rates. An electron probe micro-analyzer examines the samples after the mission.

Study on Solidification of Immiscible Alloy

Dr. Akihiko Kamio, Principal Investigator
Tokyo Institute of Technology (M-10, NASDA)

Scientists are interested in a number of alloys that cannot be produced on Earth because the components, like oil and vinegar, are immiscible. In early microgravity experiments, scientists tried to produce uniform mixtures of such materials, conducting experiments with alloys such as aluminum and indium, aluminum and bismuth, zinc and bismuth, copper and lead, and zinc and lead. However, the structures of these alloys did not show a uniform mixture of the components, and scientists have developed a reasonable theory to explain these results. The goal of this experiment is to provide additional data to confirm theoretical prediction.

During the experiment, four samples of indium and aluminum, with the amount of aluminum being varied, and one sample of copper and lead are processed in the Gradient Heating Furnace. Each sample is in a graphite container, and all five of the containers are placed in a tantalum cartridge with an ultrasonic vibrator attached. The cartridge is heated initially to 955 °C to melt all the samples. This temperature is maintained for 56 minutes, during which the ultrasonic vibrator operates for 10 minutes to mix the molten samples. The temperature is then reduced to 639 °C for 30 minutes so that only the aluminum and indium samples remain melted. The samples are cooled using the helium purge feature of the furnace. The processed samples are examined on Earth using metallurgical microscopes and other instruments to determine the alloy structure and other features of interest to scientists.



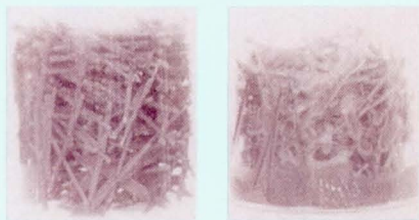
Just like the oil and colored vinegar seen here, some metals will not mix. Scientists expected an even mixture could be obtained in space but previous experiments have not shown this result.

Fabrication of Very-Low-Density, High-Stiffness Carbon Fiber/Aluminum Hybridized Composites

Dr. Tomoo Suzuki, Principal Investigator
Tokyo Institute of Technology (M-11, NASDA)

Composite materials have revolutionized many facets of everyday life, from dent-resistant automobile panels to tennis rackets. These high-strength, lightweight materials have superseded heavier conventional metals and woods. Construction in space requires materials that have these traits and, ideally, can also be manufactured on orbit. One potential material would be a finely foamed metal-ceramic composite.

There are two major difficulties with traditional foaming methods, however. The first is confining the cavities to an isolated fine state in the molten metal, which is difficult even in microgravity. The second is finding a material suitable as the foaming agent yet safe enough to use in the fabrication process.



Low-density, high-strength materials have many applications in space and on Earth. Gravity, however, limits development of these materials by interfering with the formation of proper three-dimensional arrays, as seen here in this comparison of a nylon thread/wax composite material produced in microgravity (left) and gravity (right).

Given these challenges, investigators are examining a process that may create a highly porous, lightweight, high-strength material without the need for foaming. This material would consist of short carbon fibers, aligned as random three-dimensional arrays, coated and bonded by a low-density metal alloy. A previous experiment aboard a sounding rocket showed promising results for the three-dimensional array.

For this experiment, carbon fibers are coated with an aluminum alloy using vacuum evaporation. These fibers are then cut into 1 mm or shorter lengths and encapsulated. During the mission, each sample will be processed in the Continuous Heating Furnace and the resulting composite material analyzed after the mission for strength, density, and other properties.

Study on the Mechanisms of Liquid Phase Sintering

Dr. Shiro Kohara, Principal Investigator
Science University of Tokyo, (M-12, NASDA)

Sintering is a process by which particles are joined together to form a material using heat and pressure, without reaching the melting point of one or both materials. The growth of solid particles when one of the components is melted is of interest to scientists but cannot be studied effectively on Earth because gravity segregates the solid particles. This segregation affects metallic alloys, reducing desirable traits such as strength and corrosion resistance.

Onboard Spacelab J, the reduced or eliminated segregation available in the microgravity environment should allow data representative of theoretical growth behavior to be gathered. These data will help scientists better understand, and possibly improve, sintering processes on Earth. It also raises the possibility of conducting such manufacturing in orbit.

The experiment uses tungsten and varying concentrations of nickel powder compacted into cylinders. Each cylindrical specimen is in an alumina receptacle, and five such receptacles are placed in a boron nitride container. This container is then placed in a tantalum cartridge as an additional safety measure. In this experiment, two cartridges are heated in the Large Isothermal Furnace at 1,550 °C, one for 1 hour and the other for 3 hours. After the mission, the samples are cut and polished, then examined using a metallographic microscope.

Sealing for Safety

If a container of material were to burst during the mission, it could do more than create a puddle of liquid to be dealt with or create an odor in the air as it would on Earth.

In microgravity, liquids float around as globular-shaped objects, which are at best a nuisance. In the worst case, the liquid could cause electrical shorts or be accidentally ingested by a crewmember. Molten metals could release fumes or particles that could cause similar problems. To prevent the release of any contaminant, the samples on Spacelab J are doubly or triply encapsulated.

The majority of the materials processing samples are triply encapsulated. The first encapsulation is the processing container, most often either boron nitride or quartz. This container is usually placed inside another container of the same substance and finally placed in a tantalum cartridge. Most life sciences materials are only doubly sealed, since they are not subjected to the same stresses (high heat and rapid cooling) as the materials processing samples.

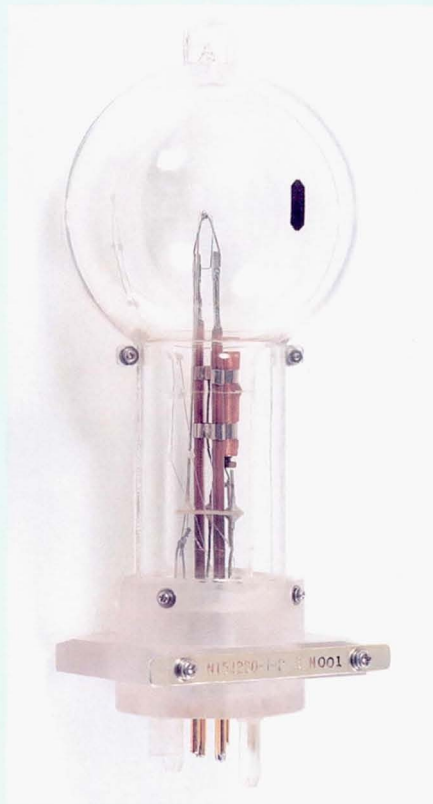
Safety tests conducted on the materials certify them for flight and ensure that failure of any one containment should not cause all containments to fail. In this way, both the safety of the crew and the successful operations of the experiments can be assured.

Gas-Evaporation in Low Gravity Field: Congelation Mechanism of Metal Vapors

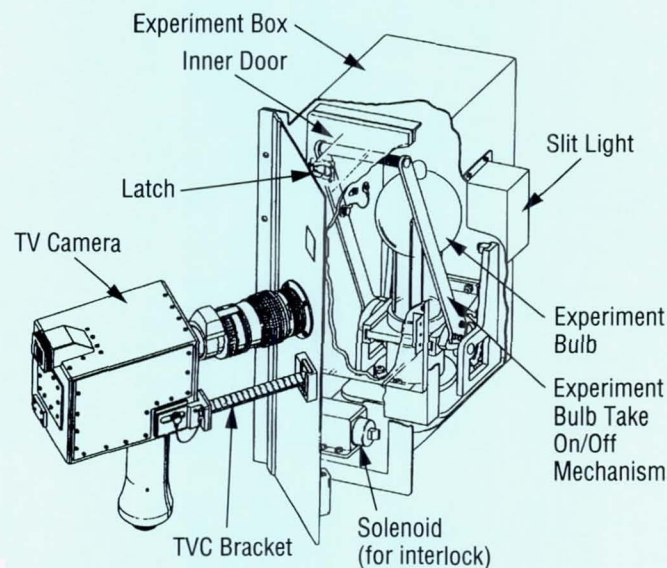
Dr. Nobuhiko Wada, Principal Investigator
Nagoya University (M-14, NASDA)

Particle formation in a gas atmosphere is extremely difficult to study on Earth. Gravity-induced convection disturbs the formation and solidification of particles, producing non-uniform particles and making study of the process difficult, if not impossible. The microgravity environment offers a solution by reducing or eliminating convection. As long as evaporation takes place at the center of a spherical chamber so that the particle dispersion is even, such studies are much easier to perform.

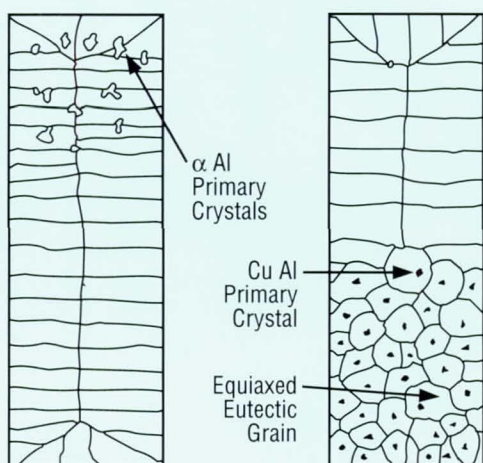
For this experiment, several glass bulbs — containing the metal to be evaporated in the center — are filled with helium or xenon gas at different pressures. During the mission, the metal samples are vaporized by heating filaments within the samples. A video camera records the motion of the particles produced, while variations in heating temperature and gas pressure are recorded simultaneously. After the flight, an electron microscope will be used to study the particles in the hope they will be of a uniform sub-micron size. Such uniform particles could be very useful to science and industry as coatings on high-density magnetic and optical recording media, electrodes, fine fluorescence screens, and for sintered materials of high-density alloys and ceramics.



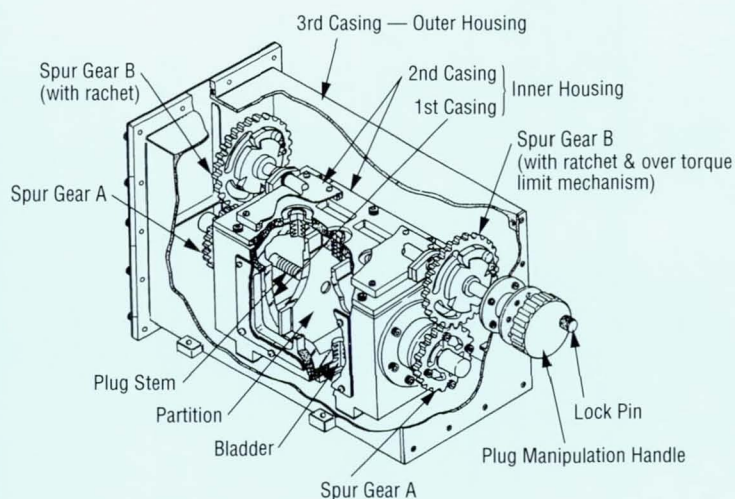
This Gas Evaporation Experiment Facility bulb contains a sample to be processed.



In this diagram of the Gas Evaporation Experiment Facility, the glass bulb containing the sample to be vaporized is visible in the upper center.



Illustrations show the structure of a hypo-eutectic alloy (left) and a hyper-eutectic alloy (right) processed under normal gravity.



The Organic Crystal Growth Experiment Facility

Solidification of Eutectic System Alloys in Space

Dr. Atsumi Ohno, Principal Investigator
Chiba Institute of Technology (M-19, NASDA)

Eutectic alloys are combinations of two or more components mixed in such proportions that the components share a common freezing, or solidification, point that is lower than that of either material alone. In this respect, the alloy acts like a single metal, having a single constant temperature for solidification.

The formation of eutectic structures, especially the relationship between primary crystals of the alloy and the eutectic grain structure, is not well understood. Gravity-induced thermal convection causes the primary crystals to break loose from their formation point on mold walls and to migrate into the solid eutectic structure, forming equiaxed grains. In microgravity, however, this should not occur.

To investigate the solidification of eutectic alloys in space, four samples of hypoeutectic and two samples of hypereutectic aluminum and copper alloys are processed for 5 minutes each at 700 °C in the Continuous Heating Furnace. The hypo- and hyper- prefixes refer to the amount of copper in the alloy in relation to the alloy eutectic point. If the alloy consists of less copper than it would at the eutectic point, it is referred to as hypoeutectic. If it contains more copper, it is then referred to as hypereutectic.

The processed samples are examined after the mission for both composition and structure. As the initial samples are unidirectionally solidified structures, changes to the structure after processing allow scientists to examine the solidification mechanisms of the space-processed alloy.

Growth Experiment of Organic Metal Crystal in Low Gravity

Dr. Hiroyuki Anzai, Principal Investigator
National Electrotechnical Laboratory (M-21, NASDA)

The purpose of this experiment is to grow two single, large crystals of the organic metal TMTTF-TCNQ (tetramethyltetrafulvalenium tetracyanoquinodimethanide). Organic metals are organic compounds that have metal atoms or ions bound to them, allowing them to conduct electricity.

In gravity, convection and sedimentation cause such crystals to be small and imperfect, making it difficult for scientists to examine their properties. Scientists want to understand these properties, since organic metals may make important contributions to electronics in the near future. In microgravity, it should be possible to grow larger, more perfect crystals for such studies. Indeed, organometallic crystals grown in microgravity may even have different physical properties, such as superconductivity, from crystals grown on Earth.

In the Organic Crystal Growth Experiment Facility, one crystal grows for nearly 8 hours in a small cell observed by a still camera. In the large crystal growth cell, growth takes place for 5 days. Because it only takes a very weak force to break them, the resulting crystals are then placed in organic solvent for protection during the return to Earth, where they are examined after the mission.

High Temperature Behavior of Glass

Dr. Naohiro Soga, Principal Investigator
Kyoto University (M-8, NASDA)

The twofold purpose of this experiment is to obtain data on the occurrence of flow in a viscous glass sphere in microgravity and to confirm data obtained on Earth for volume-temperature relationships of glass.

To do this, a spherical sample of glass laced with gold particles is heated in the Image Furnace. The sample's properties are measured at high temperature, and the expansion coefficient will be determined by measuring the volume of the sample as the temperature changes. Movement of the gold particles, if any, will determine flow within the sample.

The data from this experiment will be compared with data previously collected on Earth.

Preparation of Optical Materials Used in Non-Visible Region

Dr. Junji Hayakawa, Principal Investigator
Government Industrial Research Institute Osaka (M-17, NASDA)

The purpose of this experiment is to create a non-silicon-based glass that has superior transmission properties in the infrared wavelength region. To achieve this goal, the experiment continues the development of containerless glass-melting techniques using the Acoustic Levitation Furnace.

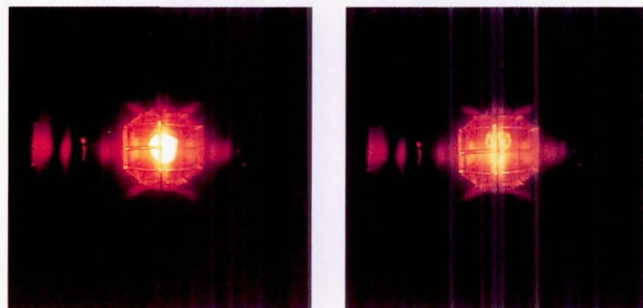
To levitate the sample, the Acoustic Levitation Furnace uses sound waves travelling between twin ellipsoidal mirrors that share a common focus. A speaker located in one mirror and a microphone in the other provide precise control of the levitation acoustics. Krypton gas, which is chemically inert, transmits the sound waves. Two halogen lamps heat the suspended sample, which is a glass composed of calcium-oxide (CaO), gallium-oxide (Ga_2O_3), and germanium-oxide (GeO_2).

Growth of Samarskite Crystal in Microgravity

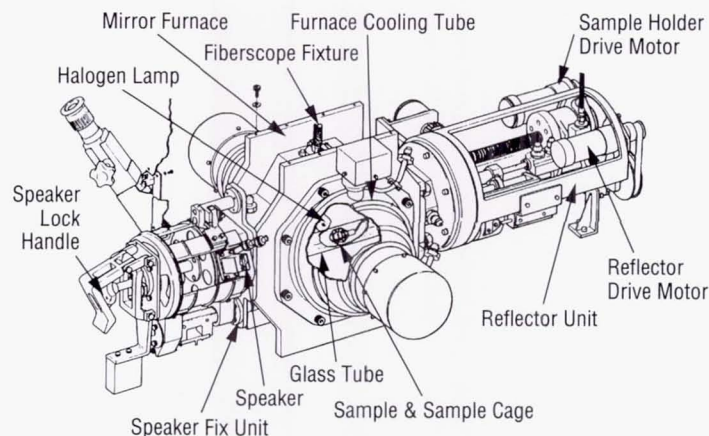
Dr. Shunji Takekawa, Principal Investigator
National Institute for Research in Inorganic Materials (M-20, NASDA)

Samarskite is an unusual mineral composed of calcium, iron, yttrium, uranium, thorium, niobium, tantalum, oxygen, and other elements. Alpha particles from the radioactive uranium and/or thorium have destroyed the original structure of the Samarskite without damaging the chemical composition and external form. Scientists wish to study this mineral because its structure is not known. By learning its structure, scientists hope to understand how it was formed.

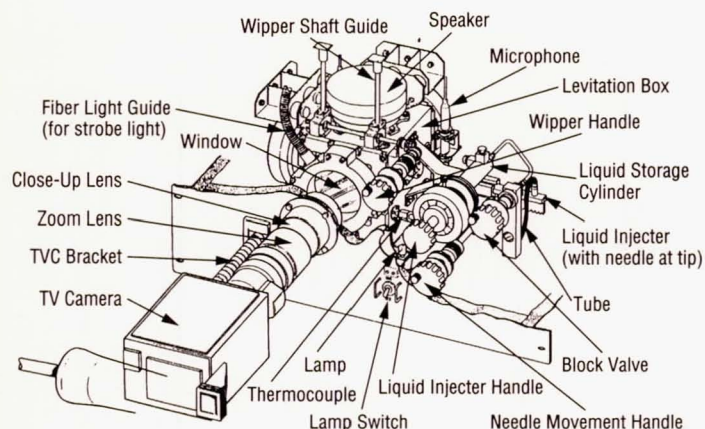
To help with these studies, a crystal is produced on Spacelab J using the travelling solvent float-zone method, and phase relationships of the Samarskite-related systems are studied in the liquid phase using the slow cooling float-zone method. A sample is placed in the Image Furnace and a melt zone created so that a single crystal can be grown. Phase relationships in the crystal will be studied during controlled cooling.



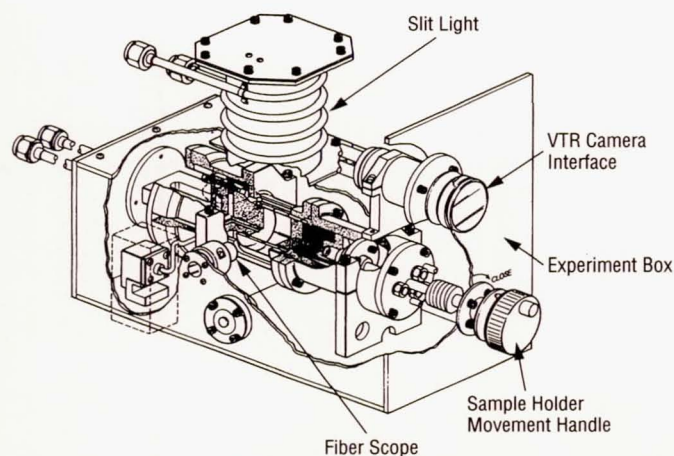
A glass sample can be seen being heated (left) and molten (right) in a test of acoustic levitation conducted during the brief period of microgravity available during parabolic flight of an aircraft.



This interior view of the Acoustic Levitation Furnace shows both the sample cage and the equipment necessary to levitate and process the sample.



The Liquid Drop Experiment Facility



**An interior view of the
Marangoni Convection Experiment Unit**

Drop Dynamics in Space and Interference with Acoustic Field

Dr. Tatsuo Yamanaka, Principal Investigator
National Aerospace Laboratory (M-15, NASDA)

This experiment uses drops of mineral oil to examine the behavior of liquid drops being levitated in an acoustic field. Drops of 10, 19, and 23 millimeters (mm) are examined in the Liquid Drop Experiment Facility to determine stable positioning, rotation, and the excitation of capillary waves (waves on the surface) on the drop. The information gathered will lead to a better understanding of drop shape and behavior, which is of fundamental scientific interest and is necessary for the development of containerless processing.

The facility consists of a cubical acoustic chamber inside which three orthogonally mounted speakers generate a standing wave. A video camera records images of the levitated drops as the phases of the sound are changed in the facility.

Marangoni Induced Convection in Materials Processing Under Microgravity

Dr. Shintaro Enya, Principal Investigator
Ishikawajima-Harima Heavy Industries, Ltd. (M-18, NASDA)

Understanding Marangoni convection is of prime importance to potential space-based manufacturers. It is especially important to determine its role in float zone melt growth. This experiment investigates Marangoni convection in paraffin by using fine aluminum flakes as tracers.

The paraffin is enclosed in a cylinder of the Marangoni Convection Experiment Unit, which has a cold "top" wall and a hot "bottom" wall. When melted (liquified), this column of paraffin simulates the melt in unidirectional growth. The free surface, subject to Marangoni convection, is formed just below the "top" wall. Controlling the temperature gradient between the two walls increases or decreases Marangoni convection. Fiber optics are used to record the motions in the column on video tape. Three experiment runs of 40 minutes each are planned for this experiment, with the last run slowly solidifying the paraffin. Particle velocity and the paths the particles follow (the stream lines) can be obtained from the video data.

Study of Bubble Behavior

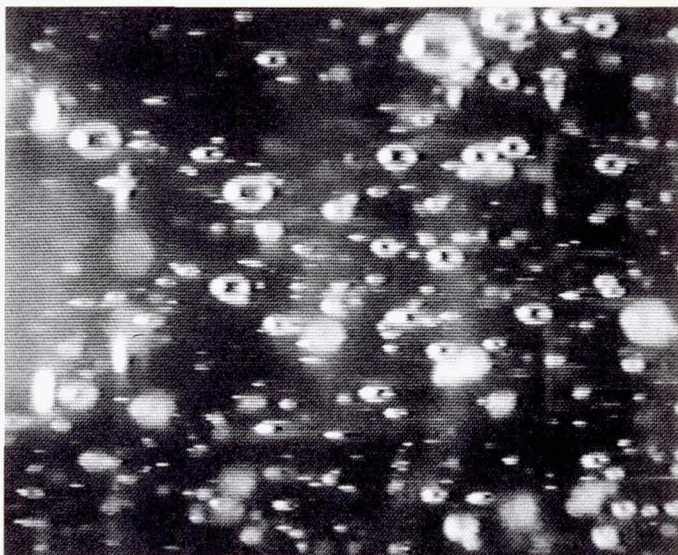
**Dr. Hisao Azuma, Principal Investigator
National Aerospace Laboratory (M-16, NASDA)**

In microgravity, bubbles in a liquid move little unless an outside force is imposed, such as Marangoni force (surface-tension-driven convection) from temperature gradients, sonic pressure from an acoustical source if used, and from residual accelerations. Sonic pressure may play a very important role in future materials processing as a means of removing bubbles from liquids or molten materials being processed in microgravity.

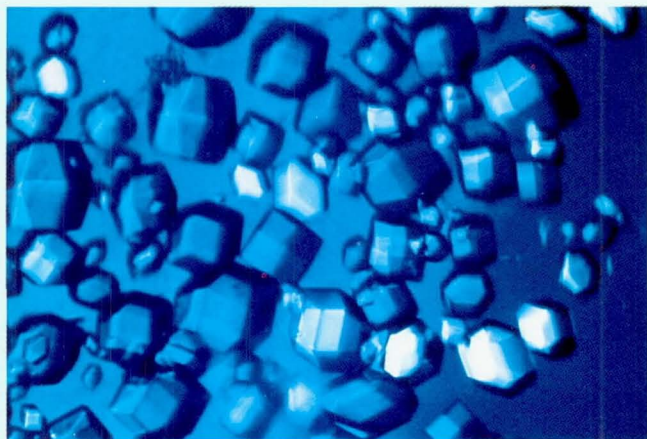
An understanding of bubble behavior under the influence of one or more of these forces is necessary for developing and refining microgravity materials processing techniques, as well as for augmenting basic scientific knowledge. The microgravity environment of Spacelab J offers a way to measure exactly the velocity of bubble migration and movement in thermal gradient and acoustic fields.

Previous bubble behavior experiments in microgravity have not examined the interaction between bubbles or bubble behavior at high Marangoni numbers (high rates of surface-tension-driven convection). The objectives of this experiment are to measure bubble migration speed over a range of Marangoni convection values, the hydrodynamic and thermal interaction between bubbles, the speed of sound in a bubble liquid, as well as to observe bubble movement and collective behavior in a stationary sonic wave.

To do this, a payload specialist uses a syringe to create bubbles or droplets in experiment cells containing silicone oil. Air is injected into two cells and water into a third cell. To create fine (small) bubbles, several large bubbles are injected, and the cell is shaken. Shaking disrupts the surface of the bubbles, causing the large bubbles to break down into numerous small ones. Various experimental conditions are imposed on the cells in the Bubble Behavior Experiment Unit, and a video camera records the results.



Bubbles are formed by injecting one large bubble into an experiment cell and shaking it.



Phospholipase crystals grown on a previous PCG mission form an interesting mosaic as they float in the microgravity environment of the growth chamber. By studying the crystalline form of proteins, scientists can learn both how and why they work.

Protein Crystal Growth

Dr. Charles E. Bugg, Principal Investigator
University of Alabama at Birmingham (NASA)

Proteins play important roles in everyday life, from providing nourishment to fighting disease. Scientists not only want to explore what each protein does but also how its structure affects those processes. X-ray crystallography is the only general method for determining the three-dimensional structures of proteins, but it requires large, single protein crystals for analysis. Crystals grown on Earth that are large enough to study can possess numerous flaws caused by gravity. Crystals grown in microgravity tend to be larger, have a more uniform internal structure, and allow much better X-ray diffraction studies of that structure. Examination of such crystals provides information on basic biological processes and could lead to the development of foods with higher protein content and more effective drugs. As a result, the Protein Crystal Growth experiment has more than 50 co-investigators from the academic and industrial communities.

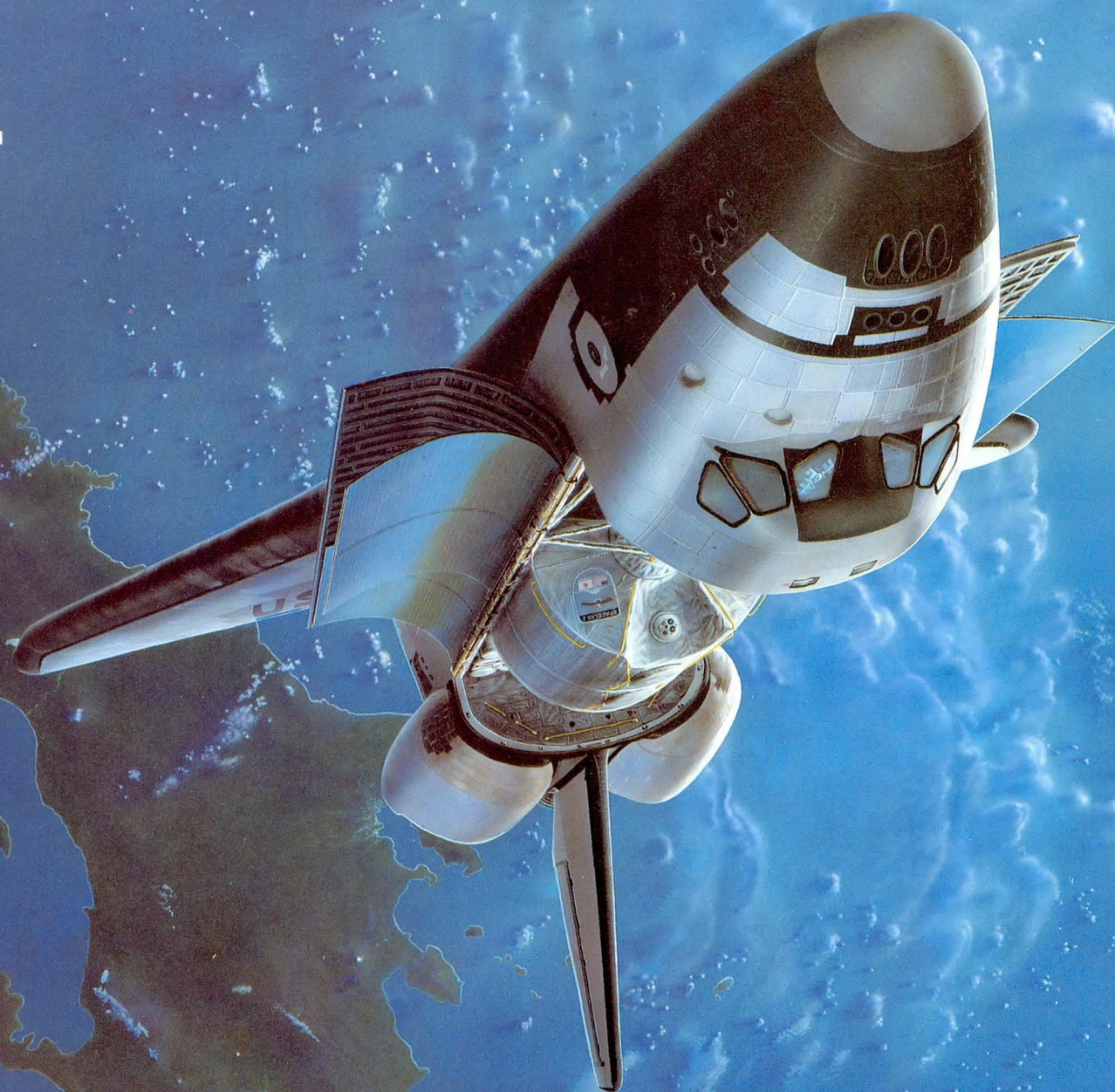


Using the data gathered with X-ray crystallography, scientists can develop a detailed three-dimensional computer model of the structure of a protein. This model of influenza neuraminidase was developed using crystals grown on a previous Shuttle mission.

The Spacelab J Protein Crystal Growth experiment uses multiple samples of 10 to 15 different proteins. The proteins are injected from one side of double-barrelled syringes into 60 temperature-controlled sample containers. The other barrel of each syringe contains a precipitant solution that causes the crystals to grow. The two solutions mix and form a drop suspended on the tip of the syringe. Crewmembers photograph the growth of crystals in each drop. Upon completion of the experiment, the drop containing the crystals is withdrawn into the syringe for postflight examination.

While NASDA considers biotechnology to be a life sciences discipline, NASA considers it to be both microgravity sciences and life sciences. Accordingly, the NASDA biotechnology experiments are listed in this section of the brochure.

Spacelab J



■ Microgravity Sciences

■ Life Sciences

Why Study Materials Science In Microgravity?

Dust settles gently onto a desktop, highlighted by a sunbeam through a window; a long fly ball arcs into centerfield where a player races to meet it; a glass-blower at a county fair spins molten glass to keep it from sagging as it is shaped; and a small child looks in wonder at the rain bouncing and splashing on the surface of a lake. Gravity is such an accepted part of our lives that we rarely think about it, even though it affects everything we do. It causes things to settle to the ground and provides an up-and-down frame of reference for our everyday lives.

The effects caused by gravity are not always desirable, however. This is especially true for certain phases of materials processing. Mixers must operate almost constantly to keep ingredients uniformly blended; molten items produced by some methods must be cooled quickly, or spun like the molten glass at the county fair, to prevent distortion of their external shape; and some products that depend on a well-ordered internal arrangement, such as electronic components, are not as perfectly ordered as they could be because of gravity's effects.

Gravity also limits scientists' efforts to study the various processes used in manufacturing and the internal changes to the structure of the material as it reaches its final form. For example, gravity is the driving force behind convection currents between hot and cold regions. These currents mask other events that scientists wish to study and can lower the quality of the final product by causing it to be improperly mixed. Gravity also causes other phenomena that can mask subjects of interest to scientists.

In a spacecraft orbiting the Earth, gravity is greatly reduced. In this environment, known as microgravity, scientists can strip away the masking effects of gravity and pursue research not possible on Earth. Conducting materials science research in microgravity may eventually lead to improvements in both production methods and final products.

There will be 27 microgravity sciences experiments conducted on Spacelab J, exploring the areas of electronic materials, metals and alloys, glasses and ceramics, fluid dynamics and transport phenomena, and biotechnology. The experiments will attempt to produce new products, evaluate new or improved production methods, and examine the suitability of microgravity for certain manufacturing processes. One technology experiment will support the others by gathering data on the acceleration environment of the Spacelab module. Examples of Spacelab J investigations include the following:

Protein Crystal Growth

Proteins play an important role in everyday life, from providing nourishment to fighting disease. Analyses of the crystal forms of proteins can reveal much about how



Larger, more perfect protein crystals, such as these lysozyme crystals, can be grown in microgravity.

they work. Earth-grown crystals that are large enough to study often have numerous flaws caused by gravity. The study of crystals grown in microgravity could lead to the development of foods with higher protein content and to the design of more effective drugs. The Spacelab J experiment will grow 10 to 15 different types of protein crystals.

Solidification Of Immiscible Alloys

Scientists are interested in a number of alloys that cannot be produced on Earth because the ingredients, like oil and water, are immiscible. Previous experiments in microgravity did not result in uniform mixtures as expected and scientists have



Just like the oil and colored vinegar pictured, some metals will not mix. Scientists expected that an even mixture could be obtained in space. However, previous experiments did not show this result.

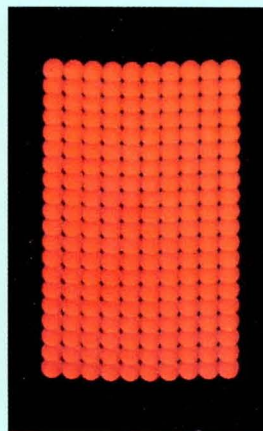
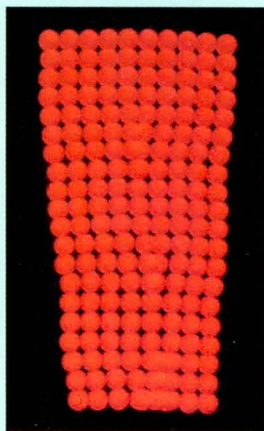
developed a theory to explain the results. The Spacelab J experiment is being conducted to help confirm the theory.



To study bubble behavior and interaction, a large bubble is injected into the chamber and the chamber is shaken to produce a large number of smaller bubbles.

Bubble Behavior

In the absence of gravity, do bubbles still rise to the top of a fluid? While experiments have been performed to answer this and other basic questions about bubble behavior in microgravity, many areas still await examination. One Spacelab J experiment will examine bubble behavior under a variety of conditions and examine how the bubbles interact with one another. These data will benefit both materials processing and basic scientific knowledge.



Gravity-induced flows can cause defects inside many materials, especially those with crystalline or lattice structures. These defects can cause structural weakness or prevent electricity from being transmitted efficiently. They also limit what can be learned about the structure and function of various crystals. Processing in microgravity can result in nearly perfect internal structure.

Why Study Life Sciences In Microgravity?

There are many reasons to study life sciences in microgravity, from obvious ones such as ensuring astronaut health to less obvious ones such as improving health care on Earth.

The human body is designed to operate in Earth's gravity field (1-g). Our skeletal structure, muscles, tendons, and ligaments developed to support our weight against this constant pull. Other systems regulate the even distribution of fluids, organize sensory input to provide us with balance and coordination, and provide a rhythm to the operations of the body. When the human body is removed from this gravitational environment, as it is when a person travels in space, many complex changes take place: bones become weaker, fluids shift toward the upper body, the daily rhythms of the body are disrupted, and a person may suffer from motion sickness until the body adapts to the new environment.

Scientists need to understand these changes so that countermeasures can be developed for long-term spaceflight. These countermeasures will help make long stays on a space station or a trip to another planet feasible. Also, studies of some of these effects can provide important new medical information that may affect many other areas — from the care of persons exposed to prolonged bedrest (such as the critically ill or injured) to those with osteoporosis.

In addition, microgravity may offer unparalleled opportunities for research on particular body systems and the production of advanced medical products. Just as materials science benefits from microgravity, so may the processing of pharmaceutical agents. New and more potent medicines are just one possible benefit of such research and processing.

Life sciences research allows us to begin planning for truly long-term stays in space by answering such questions as "Can life be conceived and develop normally in the absence of gravity?" and "What are the effects of cosmic radiation, and how can we best minimize such exposure?"

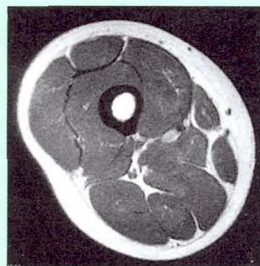
There will be 17 life sciences investigations conducted on Spacelab J, exploring the areas of cell and developmental biology, human physiology, and radiation and environmental health. One technical experiment will examine the production of medicines and the administration of medical fluids as part of the preparations for Space Station Freedom. Some examples of Spacelab J life sciences investigations include the following:

Muscle size in the legs changes with exposure to microgravity. A stocking plethysmograph, a device for measuring the volume of a limb, will be used on Spacelab J to help determine these changes. Several times over the course of the mission, an astronaut will put on the plethysmograph — similar to the one pictured — pull the tapes tight and mark them. By comparing the marks, changes in muscle volume can be measured.



Magnetic Resonance Imaging (MRI)

This experiment does not actually take place in space but on the ground before and after the mission. Unlike X-rays, which use harmful (ionizing) radiation, MRI uses low-frequency radio waves to probe the body. MRI scans allow researchers to distinguish between fat, muscle, blood, cartilage, bone, and other tissues. By doing pre- and postmission scans, researchers can determine changes not only in the size but also in the chemical composition of the body parts being scanned. The Spacelab J data can then be



This transverse MRI image details all the different structures in a portion of the thigh of a bedrest subject.

compared with those of bedrest subjects to determine the changes brought about by the microgravity environment.

Genetic Effects of HZE and Cosmic Radiation

This experiment will study fruit flies (*Drosophila melanogaster*) to investigate the possible effects of high-charge and high-energy galactic rays (HZE) and other cosmic radiation on living organisms. Of particular interest are the genetic effects. This species of fruit fly is used because mutation-inducing radiation causes cells on the fly's wing to produce several hairs, instead of the usual one hair. This mutation, therefore, is easy to spot and can provide scientists with information on radiation levels and effects. This information is useful for planning long-term missions, especially those at the altitude of Space Station Freedom, where radiation levels are higher.



Radiation causes cells on the wings of fruit flies to produce more than one hair.

Information developed from this experiment can be used by the people developing radiation protection for Space Station Freedom and similar spacecraft.

Fluid Therapy System

On Earth, patients needing fluids have a bag or bottle of the appropriate fluid hung above them and a drip initiated into a vein, a process known as intravenous (IV) fluid therapy. Gravity provides the force necessary for this process. But how can an astronaut get an IV in space? The answer is the Fluid Therapy System, being developed for Space Station Freedom. This system is designed to produce sterile water, formulate the appropriate solutions, and pump them into the patient. It will be tested under microgravity conditions on Spacelab J, so any changes needed in either the hardware or operating procedures can be made and tested again before installation on Freedom.



On Earth, gravity powers IV fluid therapy, but special equipment is needed in microgravity. The Fluid Therapy System, developed for use on Space Station Freedom, will be tested on Spacelab J.

The Spacelab J Mission

Mission Overview

Spacelab J is a joint venture between the National Aeronautics and Space Administration (NASA) and the National Space Development Agency of Japan (NASDA). Crewmembers in a pressurized Spacelab long module will perform 43 experiments — 34 from NASDA and 9 from NASA — primarily in the areas of materials processing and life sciences. These experiments will explore the suitability of microgravity for certain types of research and manufacturing, the possibilities for new materials that can only be produced in microgravity, the development of new and refined production methods, and the effects of microgravity and the space environment on living organisms.

NASDA began developing its portion, known as the First Material Processing Test (FMPT), in 1979 and contacted NASA in 1984 about conducting a cooperative effort on the Shuttle. Since the Japanese experiments did not fill the Spacelab module, NASA developed and manifested experiments complementing the theme of the Japanese investigations. Further negotiations between the two space agencies, culminating in 1991, resulted in plans to share data and samples more widely between Japanese and U.S. investigators to maximize the science return.

Mission responsibilities are shared by the U.S. and Japan. NASA provides payload integration, launch services, mission management, and some post-flight support. NASDA is responsible for selecting the Japanese experiments, overseeing their development, and ensuring that all equipment is ready for flight.

Crew *Seven crewmembers comprise the crew for the Spacelab J mission. Working in two shifts, they are an integral part of the research, both controlling experiments and participating as experimental subjects.*



Captain Robert L. "Hoot" Gibson is the Spacelab J Mission Commander. He earned his bachelor of science degree from the California Polytechnic State University in 1969, is a certified test pilot, is a graduate of the Naval Fighter Weapons School ("Topgun"), and has received numerous awards including the Distinguished Flying Cross. He has flown on STS-41B, STS-61C, and STS-27.



Major Curtis L. Brown, Jr., is the Spacelab J Pilot. He earned a bachelor of science degree in electrical engineering from the U.S. Air Force Academy in 1978, attended the Air Force Fighter Weapons School in 1983, and graduated from the Air Force Test Pilot School in 1986. Spacelab J will be his first spaceflight.



Dr. Jay Apt is the Spacelab J Flight Engineer. He earned a bachelor of arts degree in physics from Harvard University in 1971, and his doctorate in physics from the Massachusetts Institute of Technology in 1976. He has previously flown on STS-37.



Lt. Col. Mark C. Lee is the Payload Commander for Spacelab J. He earned his bachelor of science degree in Civil Engineering from the U.S. Air Force Academy in 1974 and his master of science degree in Mechanical Engineering from the Massachusetts Institute of Technology in 1980. He has previously flown on STS-30.



Dr. Mae C. Jemison, M.D., is the Spacelab J Science Mission Specialist. Before joining NASA in 1987, she worked in both engineering and medical research. She earned a bachelor of science degree in Chemical Engineering from Stanford University in 1977 and her doctor of medicine degree from Cornell University in 1981.



Dr. N. Jan Davis is the Mission Specialist assigned to Spacelab J. She earned her bachelor of science degree in Applied Biology from the Georgia Institute of Technology in 1975, a bachelor of science degree in Mechanical Engineering from Auburn University in 1977, and her master of science and doctorate degrees in Mechanical Engineering from the University of Alabama in Huntsville in 1983 and 1985, respectively.



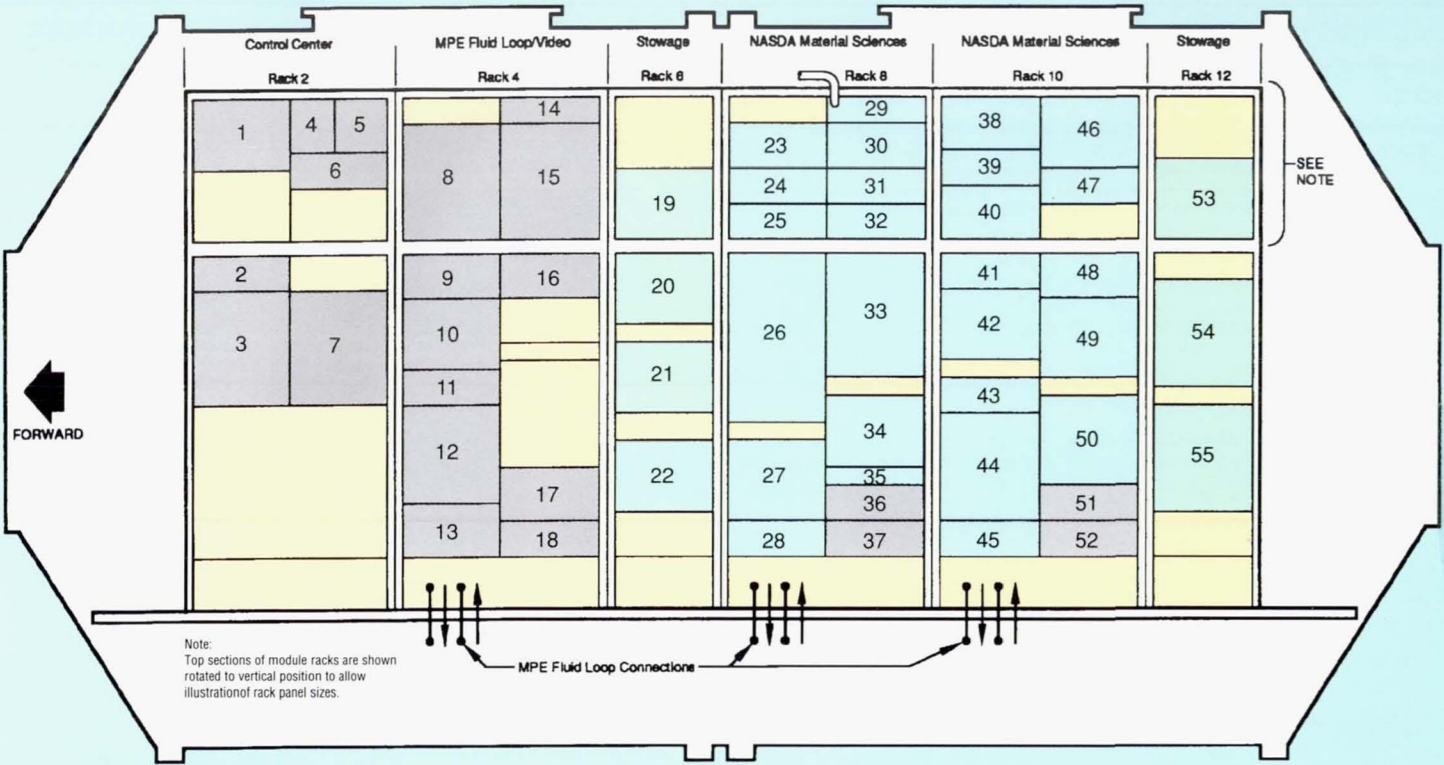
Dr. Mamoru Mohri is the first NASDA astronaut and is the Japanese Payload Specialist for the mission. He received his doctorate from Flinders University, Australia, in 1976. His major fields of study were surface physics and ultra-high vacuum science.

Mission Operations

Spacelab J is scheduled to be launched from the Kennedy Space Center to a 296-kilometer (160-nautical mile) orbit for a 7-day mission. The mission plan is ambitious: the crew is extremely busy, many experiments share the same equipment, and almost every kilowatt-hour of available energy is used. Careful planning, however, ensures a schedule that meets the needs of both the crew and the investigators.

Upon reaching orbit, crewmembers prepare the Spacelab module for operations and retrieve materials from the middeck storage lockers for use in the module. The Shuttle is positioned with its tail pointed toward Earth (known as a gravity-gradient attitude) to minimize thruster firings, which disturb sensitive experiments. A number of experiments, especially in the life sciences, begin less than 7 hours after launch to prevent damage to perishable samples, to measure changes in specimens that rapidly adapt to microgravity, and to ensure maximum exposure to the microgravity environment.

Spacelab deactivation begins near the end of the sixth day and the crew spends the seventh preparing for landing. Some 3 hours after landing, technicians remove the items stored in the middeck refrigerator/freezer, while the animal experiments are removed within 24 hours of landing.

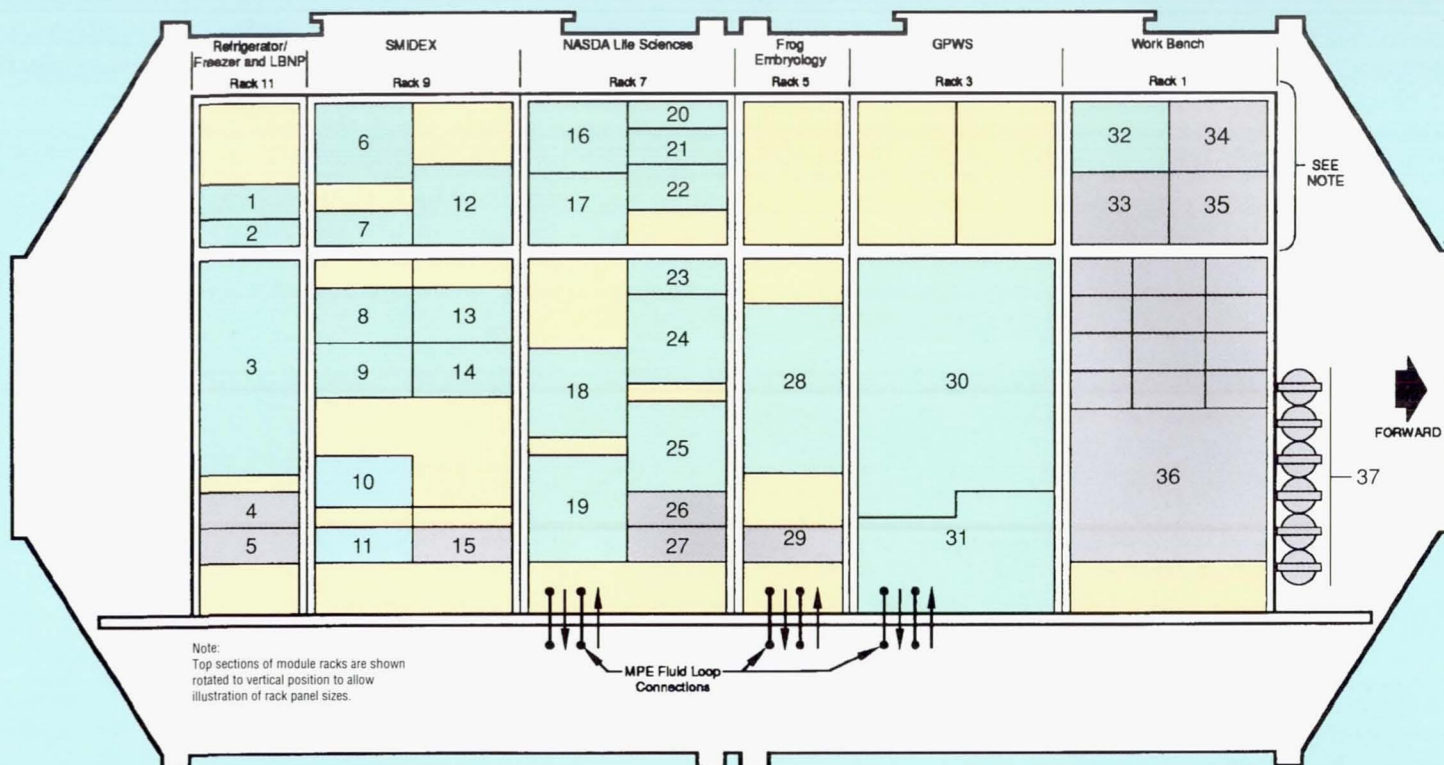
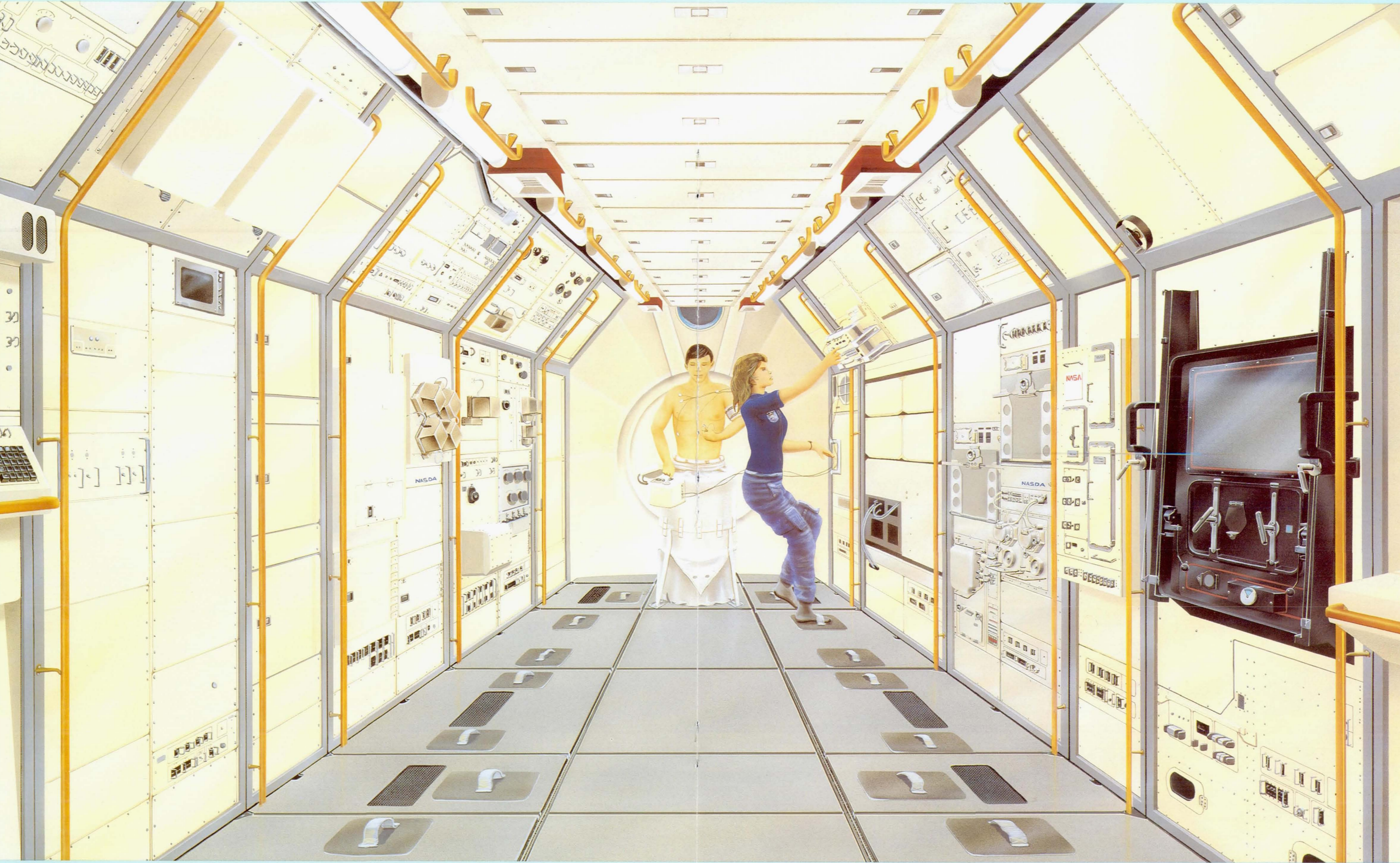


Starboard Side

- Grey = Mission Support Hardware
 Blue = Microgravity Science Related Hardware
 Yellow = Blank Closure Panels
 Green = Life Sciences Related Hardware
1. Environmental Control System Monitor
 2. Intercom Master Control
 3. High Data Rate Recorder
 4. Caution and Warning/Fire Suppression System Control Panel
 5. Pyro Control Access
 6. Electrical Power Distribution System Monitor and Control
 7. Data Display System
 8. Video Cassette Recorder
 9. Video Analog Switch Controls
 10. Intercom Remote Station
 11. Fluid Loop Monitor and Control Panel
 12. Mission Peculiar Equipment Pump System
 13. Experiment Heat Exchanger
 14. Video System Power Switches
 15. Video Cassette Recorder
 16. Television Monitor
 17. Remote Access Unit Access Panel
 18. Experiment Power Switching Panel
 19. Frog Embryology Experiment Rack Stowage Container
 20. Frog Embryology Experiment Rack Stowage Container
 21. Frog Embryology Experiment Rack Stowage Container
 22. Rack Stowage Container
 23. Sample Stowage Container
 24. Image Furnace Drive Controls
 25. Image Furnace Control
 26. Image Furnace
 27. Sample Stowage Container
 28. Power Distribution Box #1
 29. Vacuum Vent (Blue)
 30. Data Recording Video Tape Recorder

31. Central Interface and Control Equipment
32. Continuous Heating Furnace Controls
33. Continuous Heating Furnace
34. Vacuum Pump Package Equipment
35. Pilot Valve Unit
36. Experiment Power Switching Panel Access
37. Experiment Power Switching Panel
38. Organic Crystal Growth Facility
39. Large Isothermal Furnace Controls
40. Large Isothermal Furnace
41. Gradient Heating Furnace Controls
42. Gradient Heating Furnace
43. Acoustic Levitation Furnace Controls
44. Acoustic Levitation Furnace
45. Power Distribution Box #2
46. Liquid Drop Experiment Facility
47. Specific Experiment Control Equipment
48. Fluid Physics Experiment
49. Crystal Growth Experiment Facility/Gas Vapor Experiment Facility
50. Compressed Gas Supply Equipment
51. Experiment Power Switching Panel Access
52. Experiment Power Switching Panel
53. Lower Body Negative Pressure Experiment Rack Stowage Container
54. Fluid Therapy System Rack Stowage Container
55. Lower Body Negative Pressure Experiment Rack Stowage Container

NOTE: Blank closure panels cover equipment for safety and to provide proper airflow for operations.



Port Side

- Grey = Mission Support Hardware
 Blue = Microgravity Sciences Related Hardware
 Yellow = Blank Closure Panels
 Green = Life Sciences Related Hardware
1. Lower Body Negative Pressure Experiment/Life Sciences Laboratory Equipment Microcomputer
 2. Lower Body Negative Pressure Experiment Rack Interface Panel
 3. Life Sciences Laboratory Equipment Refrigerator/Freezer
 4. Experiment Power Switching Panel Access
 5. Experiment Power Switching Panel
 6. Lower Body Negative Pressure Experiment Rack Stowage Container
 7. Automatic Blood Pressure Monitoring System
 8. American Flight Echocardiograph
 9. Payload Stowage
 10. Space Acceleration Measurement System
 11. Space Acceleration Measurement System Connector Bracket Panel
 12. Fluid Therapy System Rack Stowage Container
 13. Fluid Therapy System Stowage
 14. Payload Stowage
 15. Experiment Power Switching Panel
 16. Life Sciences Stowage
 17. Life Sciences Stowage
 18. Low-Temperature Thermoelectric Incubator
 19. Free Flow Electrophoresis Unit
 20. Physiological Data (Telemetry) Interface Rack
 21. Light Impulse Controller
 22. Data Interface Unit
 23. Power Distribution Box
 24. High-Temperature Thermoelectric Incubator
 25. Vestibular Function Experiment Unit

26. Experiment Power Switching Panel Access
27. Experiment Power Switching Panel
28. Frog Environmental Unit
29. Experiment Power Switching Panel
30. General Purpose Work Station System Electronics Box
31. General Purpose Work Station Lower Electronics Box
32. Payload Stowage Container
33. Tool and Maintenance Equipment Stowage
34. Standard Spacelab Stowage Container
35. Standard Spacelab Stowage Container
36. Spacelab Workbench
37. Spare Lithium Hydroxide Canisters

NOTE: Blank closure panels cover equipment for safety and to provide proper airflow for operations.

Separation of Biogenic Materials by Electrophoresis Under Zero Gravity

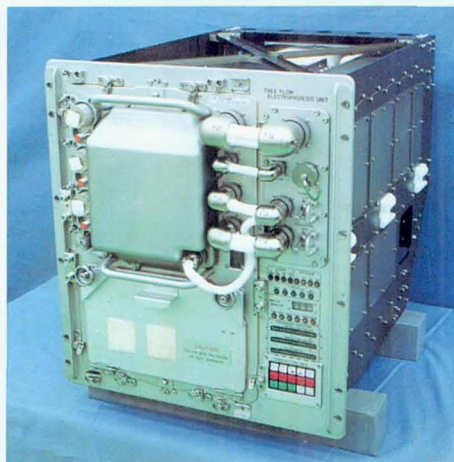
Dr. Masao Kuroda, Principal Investigator
Osaka University (L-3, NASDA)

Electrophoresis is a process for separating biological materials into individual components using an electrical field. Each element and compound has its own net electrical charge. When numerous compounds are mixed together, subjecting the mixture to an electric current causes the different compounds to separate, based on each compound's electric charge.

There are two standard types of electrophoresis. In one, the material to be separated is placed on a gel and the current applied. The second, free-flow electrophoresis, places the material into a moving stream of buffer solution. As the material passes through an electrical field, the individual components congregate into discrete streams in the solution. This method is used to process large quantities of materials, something not possible with the gel method.

While Earth-based electrophoresis processing provides better separation than many other processes, the purity of some materials still can be improved. Earth's gravity causes convection currents and sedimentation, which remix the compounds. Previous experiments in microgravity have demonstrated that free-flow electrophoresis is significantly improved in microgravity.

This experiment examines a Japanese-designed and -built electrophoresis unit and quantifies the effects of microgravity on the process. The unit separates a sample of mixed proteins (cytochrome C, bovine serum albumin, canavalin, and trypsin inhibitor) during several runs. The sample containers collected from the electrophoresis unit are stored and examined after the mission.



The Free Flow Electrophoresis Unit will process a variety of materials on Spacelab J, as well as compare the performance of a regular chamber and a thick chamber.

Protein Crystal Growth Methods

There are several methods of growing protein crystals in microgravity, some of which have been investigated on previous missions. The protein crystal growth experiments on Spacelab J will use the vapor diffusion and the liquid diffusion methods.

The liquid diffusion method, used in Dr. Morita's crystal growth experiment, mixes protein and crystallization solutions in a temperature-controlled chamber. Mixing the two solutions creates a supersaturated solution, one in which there is more of a substance than can be dissolved in the volume of fluid. As a result of this supersaturation, the protein crystals "fall out" of solution and begin to grow. This method is used to grow crystals in a short period of time, since the conditions for growth are reached almost immediately after the mixing takes place.

The vapor diffusion method also mixes protein and crystallization solutions to form crystals. In Dr. Bugg's experiment, the two solutions are contained in double-barrelled syringes. Moving a plunger mixes the two solutions in a drop suspended on the end of the syringe, which is at one end of a chamber. This chamber is lined with a wick material soaked in a very concentrated precipitant solution. Because of the difference in the vapor pressure of the two solutions, water in the drop migrates to the wick material. As this process takes place, the conditions for crystal growth are achieved and growth takes place at a uniform rate over a long period.

Each method has its advantages, and by using both on Spacelab J, scientists obtain the maximum benefit for their studies of protein crystals.

Crystal Growth of Enzymes in Low Gravity

Dr. Yuhei Morita, Principal Investigator
Kyoto University (L-5, NASDA)

As discussed in the NASA protein crystal growth write-up, proteins play a critical role in all life on Earth. From nourishing cells to coagulating blood, proteins are indispensable. As scientists understand more and more about these building blocks of life, it may become possible to produce proteins with new specific functions, which could lead to improvements in nutrition and medicine. Before such things can happen, however, scientists need to understand more about the basic structure of proteins.

On Earth, gravity limits the size and perfection of crystals that can be studied with methods such as X-ray and neutron diffraction. However, just as metal and glass crystals can be grown better in space, so can many protein crystals.

This experiment attempts to grow large crystals of a functional protein and four kinds of enzymes for structural analysis. This is done by mixing two solutions in a special chamber: one contains the protein; the other contains materials to induce crystallization. Once mixing and crystal formation are underway, the chambers must be stored in an incubator at 20 °C, both to control the rate of crystal growth and to ensure that the fluid will move as little as possible for the duration of the mission. The crystals grown in this experiment are examined after the mission.

Separation of the Animal Cells and Cellular Organella by Means of Free Flow Electrophoresis

Dr. Tokio Yamaguchi, Principal Investigator
Tokyo Medical and Dental University (L-8, NASDA)

As mentioned earlier, each element and chemical compound has its own specific electrical charge. So too do different types of cells, even cells that are very similar. Scientists, however, have not been able to separate similar cells at acceptable purity levels in normal gravity.

This experiment seeks to demonstrate the effectiveness of the microgravity environment for separating similar types of cells. To do this, scientists will attempt to obtain relatively pure samples of a strain of *Salmonella* bacteria.

They are also evaluating the effectiveness of a thick chamber in the electrophoresis unit. This chamber will be much thicker than those in use on Earth. A thick chamber offers two major advantages in processing: increased volume and reduced wall effects. By using a thick chamber, scientists can increase the sample concentration and amount, thus producing larger volumes of processed materials. Wall effects interfere with electrophoretic separation by causing some of the fluid to flow at a different rate from the rest. This means that the sample is not uniformly exposed to the electrical field, resulting in lower purity. A thick chamber, however, reduces wall effects and increases purity levels.

Space Acceleration Measurement System

Mr. Richard DeLombard, Project Manager
NASA Lewis Research Center (NASA)

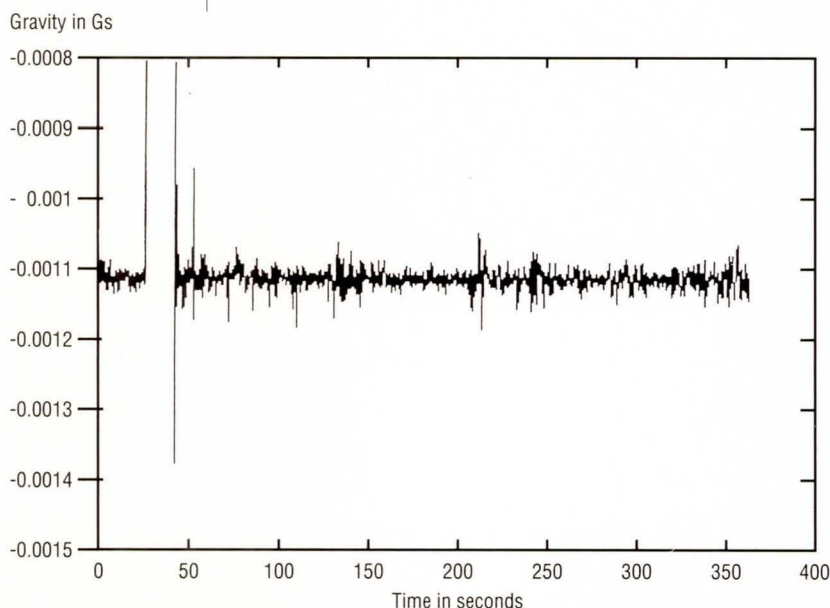
Microgravity is an ideal environment in which to conduct many different types of research. Away from the effects of Earth's gravity, purer products can be produced, larger, more perfect crystals grown, and more uniform mixtures created: including some not possible to create on Earth because of the differences in the densities of the component materials.

However, microgravity, as its name suggests, is not the absence of gravity. Although the effects of Earth's gravity are significantly reduced, crew movements, equipment operations, and Shuttle maneuvers can produce accelerations that mimic the effects of gravity. So that scientists conducting experiments in Spacelab can know what gravitational and gravity-mimicking forces may have affected their experiment, the Space Acceleration Measurement System will be flying on Spacelab J.

The system uses three sensor heads to measure accelerations along three orthogonal axes at remote locations in the Spacelab module. Data collected at each location are transmitted to a central microprocessor and stored on optical disks. The data not only benefit the scientists taking part in Spacelab J but also serve to further characterize the Spacelab acceleration environment. This characterization assists in planning future missions by allowing experiments that are extremely sensitive to vibrations and accelerations to be placed in the most advantageous location and by providing guidance to scientists designing experiments and equipment for Spacelab.



Three triaxial sensor heads, like this one, will be located in different parts of the Spacelab module during Spacelab J. Each head sends data back to the central processing unit, mounted in the center aisle of the module.



This typical Space Acceleration Measurement System data plot, obtained on the IML-1 mission, shows a portion of the acceleration data from a triaxial sensor head. Scientists conducting experiments can obtain data from one or all three remote sensor heads to determine the acceleration environment to which the experiment was exposed during the mission.

Life Sciences

Sixteen investigations examine three areas of life science — cell and developmental biology, human physiology, and radiation and environmental health. These experiments seek to discover the effects of the space environment on life forms, identify ways to correct or prevent problems associated with working and living in space, and improve the quality of life on Earth by advancing knowledge in biological sciences. In addition, one technology experiment will examine the production of medicines and the administration of medical fluids as part of the preparations for Space Station *Freedom*.

Why Conduct Life Sciences Research in Microgravity?

A fundamental reason for doing life sciences research is, of course, to understand the changes brought about in plant and animal life as a result of the microgravity environment. What happens to organisms when normal environmental cues, such as gravity, are removed? Can life develop normally without them?

Scientists are extremely interested in these questions. Data from life sciences research can lead them to ways of controlling such problems as Space Adaptation Syndrome (a condition experienced by astronauts similar to motion sickness) and bone density loss in humans. They may also develop a better understanding of many of the basic mechanisms of both human and plant physiology. From bone development and growth to the development and growth of entire organisms, the mechanisms that control various processes can be identified, studied, and perhaps eventually controlled. This knowledge could lead to a better understanding of a variety of injuries and diseases and the development of hardier and more nutritious plants. Such plants could help combat hunger and pollution on Earth, as well as provide food and oxygen during long-term space efforts.

Just as experimenting in microgravity can benefit materials processing, so too can it benefit biological processing. The microgravity environment is ideal for the production and refinement of drugs and other biological materials. Gravitational effects such as sedimentation and thermal convection are reduced or eliminated, allowing greater quantities of materials to be refined or produced at higher levels of purity than possible on Earth. It has been previously estimated that more than 25 million people a year could benefit from space-based free-flow electrophoretic processing of biological materials such as interferon, antihemophilic products, growth hormone products, and beta cells.

The experiments on Spacelab J examine many of these areas, from research into the causes and control of Space Adaptation Syndrome to the evaluation of a thick-chambered free-flow electrophoresis unit. While these experiments may not provide the ultimate answer to any of the questions being investigated, they are an integral part of finding those answers and solutions to both Earth and space-based problems.

Plant Culture Research (Gravity, chromosomes and organized development in aseptically cultured plant cells)

Dr. Abraham Krikorian, Principal Investigator
State University of New York at Stony Brook (NASA)
Co-Investigation with Dr. Atsushige Sato, L-6

As discussed earlier, there are many questions about cell development in microgravity. The potential problems related to early developmental stages may affect not only animal life but plant life as well.

This experiment uses aseptic carrot and daylily cultures to investigate how microgravity affects plant cell division and development. Specifically, it examines the effects on growth and differentiation of plant cells, and on mitosis and chromosome behavior.

The experiment uses NASDA-provided petri dish-type metal culture chambers. A precisely controlled semi-solid agar based nutrient (enabling) medium is distributed throughout a honeycomb support structure. This medium will allow the cultures to grow from unorganized cells into embryos, if the microgravity conditions are favorable for growth. The cultures are analyzed on the ground using conventional and scanning electron microscopes and chromosome analysis.

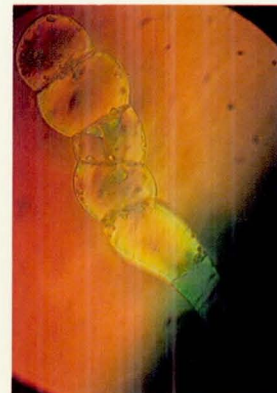
Studies on the Effects of Microgravity on the Ultra-structure and Function of Cultured Mammalian Cells

Dr. Atsushige Sato, Principal Investigator
Tokyo Medical and Dental University (L-6, NASDA)

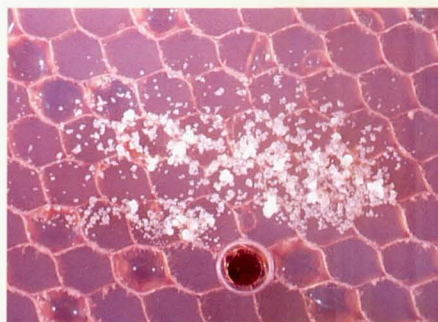
Despite numerous studies of cultured animal cells during spaceflight, scientists do not fully understand the influence of microgravity on cell structure and function. To better understand how microgravity affects animal cells, this experiment grows cell cultures in a thermo-electric incubator.

Four cultures of kidney epithelial cells are grown on orbit using a commercial growth medium supplemented with 10-percent fetal bovine serum, which provides nutrients for the cells. Two cultures will be treated in orbit with trypsin, an enzyme which breaks cells free from each other and from the walls of the culture chamber, and fixed with glutaraldehyde. The first culture is fixed immediately after trypsinization and the second after 24 hours. These two are stored at 4 °C until they are examined on Earth. Cells in a third culture are harvested after being grown in serum-free medium for 48 hours; then the medium is frozen. The fourth culture is used to observe microscopically any effects of microgravity on the cells.

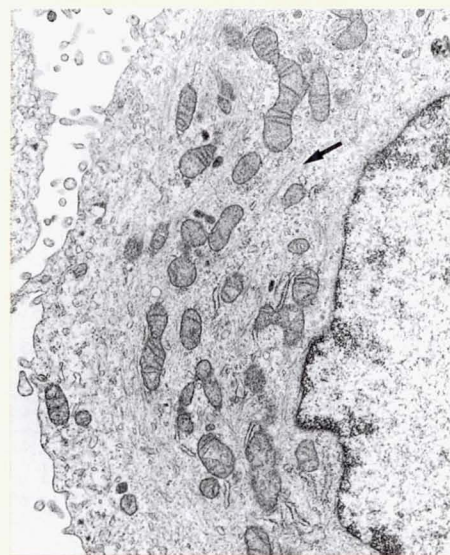
By examining these cultures using electron microscopes and chemical analysis, scientists hope to observe the rearrangements of intermediate filaments and microfilaments in the cell. These filaments, which compose the skeletal structure of cells and moderate cellular functions such as mitosis (cell division), can be examined using an electron microscope. Other analyses examine the nutrient consumption and urokinase (an enzyme that dissolves blood clots) productivity of the cultures.



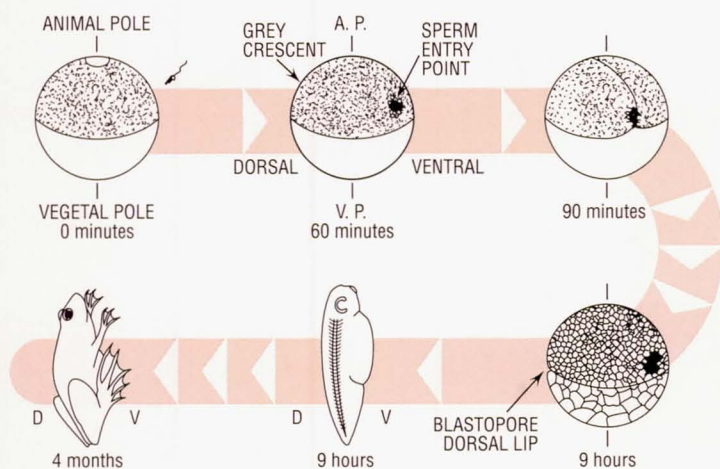
This microscopic view shows an early stage of a carrot embryo derived from a body (somatic) cell. One of the goals of the Plant Culture Research experiment is to determine if such embryos will form in microgravity.



This close-up view shows daylily embryos growing on a nutrient medium within a honeycomb support structure. The extent to which such development will occur in microgravity will be examined on Spacelab J.



Intermediate and micro- (arrow) intracellular filaments are visible in this electron microphotograph of a cell.



The development of an egg into an adult frog is seen in this progression which shows the sperm entry point determining dorsal/ventral axes.



This photograph shows fertilized frog eggs that have rotated with respect to gravity. The heavier yellow hemisphere points toward gravity, while the lighter brown hemisphere points away from gravity. The dark spot appearing on some eggs is where the sperm penetrated the egg.

The Effects of Weightlessness on the Development of Amphibian Eggs Fertilized in Space

**Mr. Kenneth A. Souza, Principal Investigator
NASA Ames Research Center (NASA)**

Many people look forward to long-term space ventures, from missions to Mars to space colonization, but before living and working in space is attempted, numerous questions must be answered. Two extremely important ones are: What role does gravity play in the early development of an organism? Can new generations of a species be conceived and develop normally in microgravity?

This experiment examines aspects of these questions by investigating the effect of microgravity on amphibian development. The role of gravity in amphibian development has been the subject of considerable debate. Previous experiments have failed to provide conclusive data, since the experimental procedures may have been flawed because the fertilization of the eggs took place on Earth. It is now believed that the portions of development most sensitive to gravity may occur during and just after fertilization.

To examine this theory, female frogs carried aboard Spacelab J are induced to ovulate and shed eggs. These eggs are then fertilized in the microgravity environment. Half are incubated in microgravity, while the other half, serving as a control group, are incubated in a centrifuge that spins to simulate normal gravity. At various times, some eggs from both groups are fixed with formaldehyde and stored for postmission examination. The remaining eggs develop undisturbed until after the mission so further studies can be performed, including examinations of the swimming behavior of tadpoles grown in the absence of gravity.

Of particular interest is the role of gravity in the process of bilateral symmetry, dorsal/ventral axis formation, and the development of the inner ear and related gravity-sensitive components. Normally, female frogs shed their eggs into rivers, streams, or other bodies of water. Male frogs release sperm in close proximity to the eggs. After a sperm enters an egg, the egg rotates in response to gravity, and the dorsal structures, better known as the future backbone, form opposite the point where the sperm entered.

For more than a century, embryologists (scientists who study the development of animals from the fertilization of eggs to maturity) have wondered whether egg rotation to align with gravity is essential for normal development. This experiment may provide the answer. Scientists expect that microgravity will not significantly alter the normal process of amphibian fertilization and development. However, they do expect that gravity-sensing structures, such as the inner ear, may differ from normal and that there could be abnormalities in subsequent development and reproduction. If confirmed, this could pose problems for the long-term presence of other species, including humans, in space unless gravity is artificially induced so that conception and development can take place normally.

Autogenic Feedback Training Experiment: A Preventative Method for Space Motion Sickness

**Dr. Patricia S. Cowings, Principal Investigator
NASA Ames Research Center (NASA)**

Autogenic Feedback Training was developed as a method to control or minimize space motion sickness without the use of drugs, using biofeedback techniques. This experiment flew previously on Spacelab 3, but the hardware has been extensively redesigned to allow better data collection and improve crew comfort. Two volunteer crewmembers on Spacelab J act as subjects for the experiment. One receives training in voluntary control of his or her physiological responses to motion sickness stimulation. The other does not and serves as a control subject.

Instruments within the Autogenic Feedback Suit measure each crewmember's pulse rate, blood pressure, skin temperature, blood volume, skin conductance, respiration, and head accelerations in three orthogonal axes on a continuing basis. The suit is worn at all times except during sleep periods. Participants can check their current physiology on a wrist display unit, which displays heart rate, blood volume, respiration rate, and skin conductance, as well as the time. Trained individuals use this information to control their physiology and suppress symptoms. Augmenting these data is a written log of symptoms experienced by the crewmember.

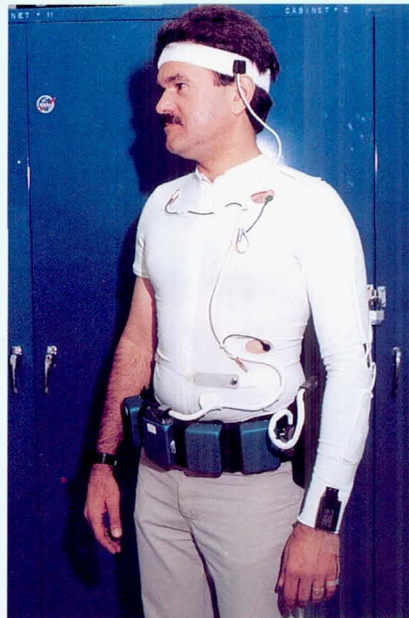
Before the mission, both participants have preliminary data taken and undergo motion sickness stimulation. The experimental subject receives 6 hours of training on how to control the appropriate physiological responses. This crewmember is also encouraged to continue practicing these techniques using portable Autogenic Feedback Training equipment.

The use of this experiment on Spacelab J will expand the experimental sample size, which calls for acquiring data from a total of 16 subjects, half of which form the control group. Analysis of the data will allow Autogenic Feedback Training to be evaluated as a countermeasure for space motion sickness by comparing inflight data with ground-based motion sickness data. This could lead to the ability to predict crewmember susceptibility to space motion sickness.

Bone Cell Research

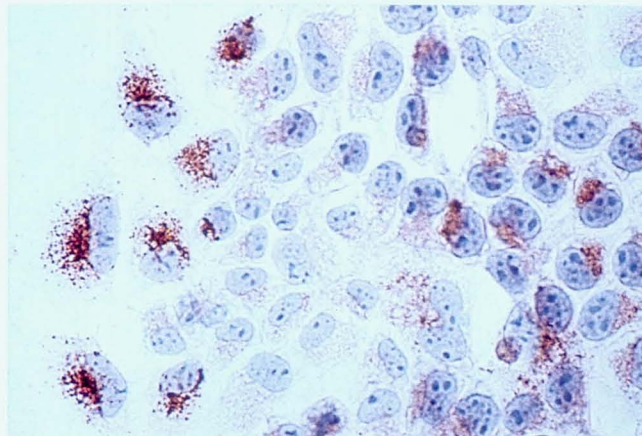
**Dr. Nicola Partridge, Principal Investigator
St. Louis University School of Medicine (NASA)
Co-Investigation with Dr. Atsushige Sato, L-6**

As humans begin to work and live in space, the effect of microgravity on bone growth and mineralization becomes increasingly important. From previous spaceflights, it is known that bones can be weakened by the absence of gravity. This results from a complex process that includes less new bone formation (rather than an increase in bone breakdown), changes in bone shape, redistribution of minerals and fluids, and weaker muscles. Given these



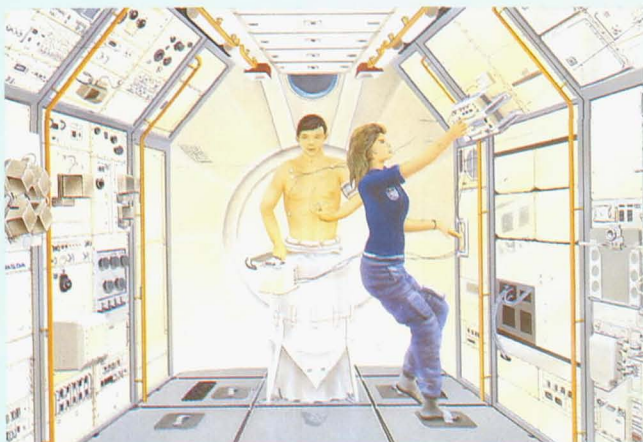
The Autogenic Feedback Training System 2 suit, seen here being worn by alternate Payload Specialist Dr. Stanley Koszelak, provides information from a variety of sensors for both crewmember use in combating Space Adaptation Syndrome and for post-mission analysis.

These osteoblastic cells have been stained to show the production of a collagen-degrading enzyme. Osteoblastic cells grown on Spacelab J will be examined by a variety of methods to help answer questions about the effects of microgravity on bone cells.



The Lower Body Negative Pressure equipment undergoes testing prior to Spacelab J. On-

orbit, the equipment will be used to simulate orthostatic intolerance and test a countermeasure for this condition.



On Spacelab J, the Lower Body Negative Pressure Device will be located at the aft end of the Spacelab module.

effects, what might happen to the bones of people working for extremely long durations in space or to those of children growing up there?

This experiment attempts to answer some of the questions about bone changes by examining the effects of microgravity on bone cell responsiveness, shape, and protein production. This is done by growing cultures of rat osteoblastic cells (bone forming cells) in a thermoelectric incubator using the same type of chambers as for experiment L-6. Investigators study these cultures through the use of photomicroscopy and biochemical analysis to determine whether the cells change either shape or function compared to cultures maintained on Earth. By understanding how spaceflight causes changes in bone cell function, scientists can better understand why bones become weaker during spaceflight.

Lower Body Negative Pressure: Countermeasure for Reducing Postflight Orthostatic Intolerance

**Dr. John B. Charles, Principal Investigator
NASA Johnson Space Center (NASA)**

Over the course of a mission, television viewers might notice that astronauts' faces become puffy and swollen. This is because fluids tend to migrate out of the lower body toward the head and chest in the absence of gravity. While not a problem in orbit, the fluid shift and associated fluid loss can cause problems when the astronauts return to Earth. Because of fluid loss, astronauts returning to Earth can experience reduced blood flow to the brain when standing up, raising their pulses and possibly causing a loss of consciousness.

The investigators hypothesize that orthostatic intolerance, as the condition is known, can be countered by ingesting a liter of isotonic saline solution while exposing the lower body to a reduced atmospheric pressure. This lower pressure should cause fluids to redistribute to the lower body, where they should remain for up to 24 hours.

The Lower Body Negative Pressure experiment uses a cylindrical fabric device, which seals around the waist of the astronaut, as a pressure vessel. This cylinder, attached to the floor of the Spacelab module, has a controller that operates a pump to change the pressure inside it. The experiment on Spacelab J attempts to simulate orthostatic intolerance using negative pressure and to evaluate the effectiveness of the saline ingestion during Lower Body Negative Pressure as a countermeasure.

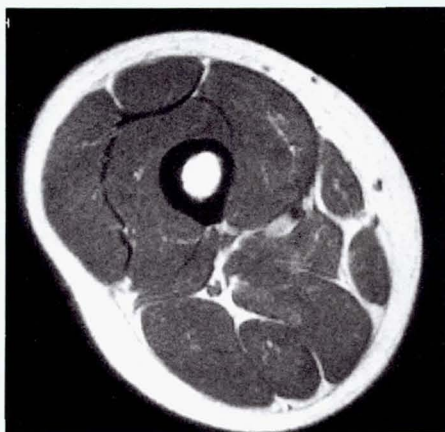
Effectiveness of the treatment is determined by examining data from an echocardiograph, an automatic blood pressure monitoring system, and an ultrasonic limb plethysmograph (a device for measuring the size and volume of a limb and establishing the changes in these parameters). This equipment monitors pulse rate, blood pressure, cardiac dimensions and function, calf dimensions, and leg volume so that fluid shifts and physiological responses can be determined.

Magnetic Resonance Imaging (MRI) After Exposure to Microgravity

Dr. Adrian LeBlanc, Principal Investigator
Baylor College of Medicine and Methodist Hospital (NASA)

This experiment does not actually take place in space but on the ground before and after the mission. It seeks to develop Magnetic Resonance Imaging as a non-invasive tool for studying physiological changes brought about by exposure to microgravity and to compare data from Spacelab J crewmembers with those of bedrest patients. Assessments will be made of muscle atrophy and bone marrow and vertebral disc changes.

Unlike conventional X-rays, which use ionizing radiation, Magnetic Resonance Imaging uses low-frequency radio waves to probe the body, giving the process no known health hazards. Magnetic Resonance Imaging is sensitive to hydrogen and actually forms its image by "reading" the hydrogen in the area being scanned. The scan not only measures the quantity of hydrogen in an area, but distinguishes between the different chemical forms of the element — allowing researchers to distinguish between fat, muscle, blood, cartilage, bone, and other tissues. This sensitivity to



chemical form also allows researchers to detect shifts in the chemical makeup of a region, allowing them to detect subtle changes or injuries.

The procedure for this experiment is relatively simple. Before the mission, the crewmembers taking part in this experiment have scans made of their legs and spines. After landing, similar scans are performed, and comparisons are made between the two sets of scans. In particular, the investigators examine the muscle volume in the calf and thigh, fat and water changes in spinal bone marrow, and changes in the volume, shape, and water content of the spinal discs (vertebrae). The changes found are compared to the changes in subjects undergoing a bedrest experiment in Houston. By comparing data from the two groups, the astronauts and the bedrest subjects, researchers hope to understand better the mechanisms behind muscle atrophy and the effects of reduced gravity on the spine. This could not only benefit astronauts but also patients whose injuries or illnesses require prolonged periods of bedrest.

This Magnetic Resonance Imaging transverse image of a human leg shows the many different structures within that section, including the soft tissues that X-rays cannot image. Since MRI uses low-frequency radio waves, rather than harmful ionizing radiation like X-rays, there is no known health hazard to its use.

Health Monitoring of Japanese Payload Specialist

Dr. Chiharu Sekiguchi, Principal Investigator
NASDA (L-0, NASDA)

In addition to science collaboration with the Autogenic Feedback Training Experiment, this investigation uses a physiological monitoring system and echocardiography to monitor the Japanese payload specialist during flight. For the Japanese, this is an opportunity to examine first hand the effects of microgravity on human physiology.

They are particularly interested in the adaptation process and how it relates to space motion sickness and cardiac deconditioning. By comparing data from their own experiments to data collected by others, they hope to understand the processes involved and find ways to avoid these problems for future Japanese astronauts onboard Space Station *Freedom* and on Japanese space ventures.

Endocrine and Metabolic Changes in Payload Specialist

Dr. Nobuo Matsui, Principal Investigator
Nagoya University (L-1, NASDA)

Spaceflight and adaptation to microgravity place a variety of stresses on the human body. These stresses, along with the adaptation process, result in changes to normal body biochemistry.

To quantify and understand these changes better, this investigation examines blood and urine samples taken from the Japanese payload specialist. The payload specialist records the type and quantity of fluid intake during the mission for use in the examinations. By analyzing the blood and urine samples, investigators hope to assess stress reactions by determining the presence and levels of stress hormones, to determine the relationship between upward fluid shift and water-electrolyte metabolism and the associated regulatory hormones, to clarify the relationship between bone-muscle atrophy and anabolic and catabolic hormone secretion, and to study the circadian rhythm of hormone secretion.

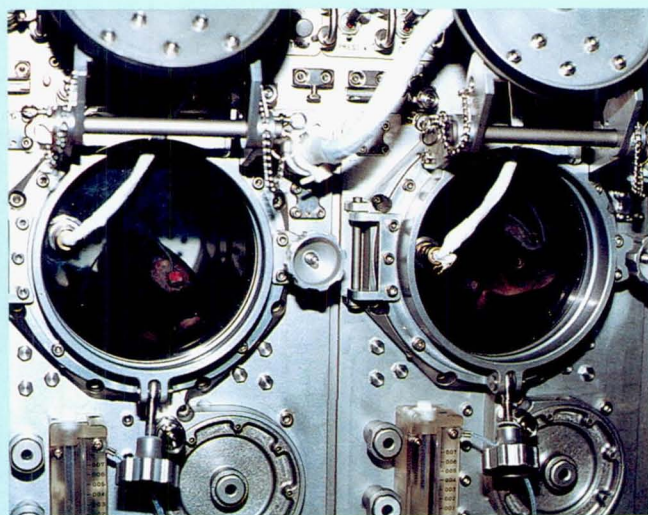
Neurophysiological Study on Visuo-Vestibular Control of Posture and Movement in Fish During Adaptation to Weightlessness

Dr. Shigeo Mori, Principal Investigator
Nagoya University (L-2, NASDA)

Many people going into space suffer from Space Adaptation Syndrome for the first day or two after launch. One possible explanation for this could be sensory conflict, caused by differing signals sent to the brain from the eyes and inner ear.

To gather data on this theory, two carp are flown in a special facility on Spacelab J. One carp has had its otolith, a gravity-sensing organ, removed. On each carp, an electrode placed on the cerebellar surface is connected to a pre-amplifier on the skull.

Twice a day during the mission, the carp are subjected to light coming alternately from the top and side of the containers while video and brain wave recordings are made. The data collected allows scientists to identify adaptation to microgravity through the reaction to the light and through the cerebellar activity. By comparing the data from each fish, scientists can determine the extent of sensory conflict as a contributor to Space Adaptation Syndrome.



This photograph shows fish in the Vestibular Function Unit during ground tests. In microgravity, the fish are expected to rotate as the light is moved from the top to the side of the experiment chamber.

Comparative Measurement of Visual Stability in Earth and Cosmic Space

Dr. Kazuo Koga, Principal Investigator
Nagoya University (L-4, NASDA)

Another possible contributor to Space Adaptation Syndrome is the loss of visual stability caused by a lack of cooperative movements between the eyes, head, and body.

To examine this theory, the Japanese payload specialist attempts to track a flickering light target while eye movements and neck muscle tension are measured. This is done in four different positions in relation to the Spacelab module — rightside up, upside down, and two different 45-degree angles. An electrode attached near the eye monitors head and eye movement, while another monitors neck muscle tension. A camera records the payload specialist's face, and the principal investigator monitors the experiment from the ground to make changes in the experiment as needed.

The Effect of Low Gravity on Calcium Metabolism and Bone Formation

Dr. Tatsuo Suda, Principal Investigator
Showa University (L-7, NASDA)

The loss of calcium from bones and the resultant loss of bone density during spaceflight has been well documented. These problems appear to result from a decrease in bone formation rather than from bone resorption and are related to the length of the spaceflight. Before humans can live and work for truly long periods of time in space, this process must be fully understood and countermeasures developed.

To understand the mechanism behind the halt in bone formation, 30 fertilized chicken eggs are flown on Spacelab J, while 30 remain on the ground as a control group. The eggs are different ages: 5 are 0 days old, 5 are 2 days old, 10 are 7 days old, and the final 10 are 11 days old. At the end of the mission, they are 7, 9, 14, and 18 days old. Some of the eggs are examined immediately after landing for cartilage growth, bone formation and resorption, differentiation of chondroblasts (collagen-forming cells), osteoblasts (bone-forming cells) and osteoclasts (bone-degrading cells), biosynthesis of actin and myosin (muscle proteins responsible for contraction), muscle fiber formation, collagen biosynthesis, and calcium and vitamin D metabolism. The results of these experiments are compared to those of an equal number of the control group. The rest of the embryos are allowed to develop normally so that further data can be obtained on future development.

The results from this experiment could not only help astronauts but also people subjected to prolonged bedrest on Earth.

Research on Perceptual-Motor Functions Under the Zero Gravity Condition

Mr. Akira Tada, Principal Investigator
National Aerospace Laboratory (L-10, NASDA)

Using the same equipment as the visual stability experiment (L-4), this investigation obtains data on human function and performance in tracking control operations. Such data could help determine how much automation is needed to assist a pilot in flying a spacecraft.

Unlike the visual stability experiment, the payload specialist remains in one position. As the light target moves, the subject moves a joystick to match the target's movements. In addition to data on eye movement and neck muscle tension (to determine physiological changes caused by microgravity), the movements of the joystick will be compared to the movement of the target so that operator characteristics, tracking performance, and hand movement effectiveness can be evaluated.

Circadian Rhythm of Conidiation in *neurospora crassa*

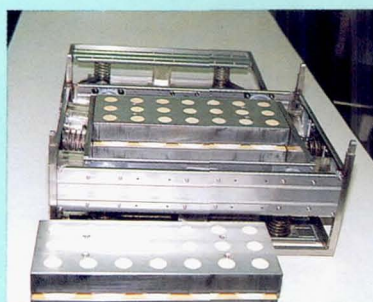
Dr. Yasuhiro Miyoshi, Principal Investigator
Tokyo University (L-12, NASDA)

Many life forms exhibit a circadian rhythm, a cycle of activities based on Earth's 24-hour day. A prime example of circadian rhythm is the human sleep cycle. But does this cycle hold true in space, away from Earth?

To determine if these rhythms still occur away from the influences of Earth, scientists are experimenting with a strain of *neurospora crassa*, a fungus, to see if it still follows normal spore formation cycles and if they differ from the cycles on Earth. A special fungi growth chamber in Spacelab is kept for 1 day in constant light at 20 °C. The crew photographs the fungi growth front; then, the chamber is placed in the dark for 5 days, also at 20 °C. The crew again photographs the growth front and stores the culture in a refrigerator for postflight analysis.

Delivering Eggs to Space

While the Shuttle is the most gentle ride into space NASA has ever had, occupants are still subjected to several times their own weight in acceleration forces. In addition, vibrations occur across a broad spectrum of frequencies.



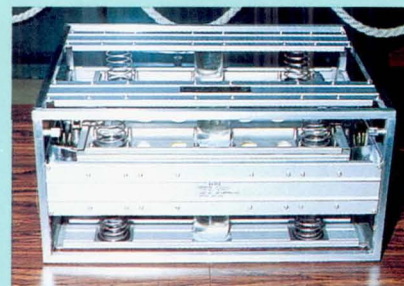
Chicken eggs can be seen safely nestled in their protective padding in this photograph of the Spacelab J egg rack. The rack was developed to protect the eggs from the forces and vibrations of flight.

Getting fertilized eggs safely into orbit for experimentation on Spacelab J has been difficult. First, the eggs must be protected from the forces of launch and landing. Second, they must be protected from certain frequencies of vibrations, as those vibrations would kill the developing embryos.

For the flight, a new egg rack was designed to hold the eggs firmly in place and in the proper position for launch and landing. Placing them in the proper position reduces strain on each egg, while the restraints prevent them from breaking against each other.

Certain frequencies of vibration were the major concern with the egg rack. To eliminate them, a tuned padding and suspension system was developed to eliminate the majority of harmful vibrations.

With these problems controlled, scientists are able to complete their experiments without breaking an egg.



With the egg holder mounted in place, the egg rack's tuned suspension and padding prevents harmful vibrations from killing the embryonic chickens, as well as keeping the forces of launch and landing from breaking the shells.

Genetic Effects of HZE and Cosmic Radiation

Dr. Mituo Ikenaga, Principal Investigator
Kyoto University (L-9, NASDA)

It is well known that certain high-energy radiation can destroy cells, induce mutations or malignant tumors, or even kill if exposure is high enough. Earth's atmosphere and magnetic field screen out most harmful radiation, but that protection is obviously reduced or eliminated for people in space. The higher one goes in orbit, the more exposure there is to radiation; therefore, the types, amounts, and effects of radiation impacting the Shuttle or any space structure are of no small concern. While previous experiments have shown the dosage of harmful radiation during a 7- to 10-day Shuttle flight to be so small as to pose no hazard, this can be a concern for Space Station *Freedom* and similar structures designed to support long-term life in space.

This experiment seeks to examine the possible effects of high-charge and high-energy cosmic rays (HZE) and other cosmic radiation on living organisms, particularly the genetic effects.

To do this, fruit fly larvae of the species *Drosophila melanogaster* are incubated in special fly containers and the containers placed in different locations in Spacelab. This particular species is used because, while each cell on the fly's wing normally produces only one hair, mutation-inducing radiation causes more than one hair to grow. This mutation is easy to spot and can provide scientists with information on radiation levels and effects.



The passage of ionizing radiation is easily detected in this photograph of a fruit fly wing. While each cell normally produces only one hair, the exposure causes cells to grow multiple hairs.

Study on the Biological Effect of Cosmic Radiation and the Development of Radiation Protection Technology

Dr. Shunji Nagaoka, Principal Investigator
NASDA (L-11, NASDA)

This experiment is also concerned with HZE radiation and its biological effects. However, it seeks to measure the amounts and types of radiation inside spacecraft like the Space Shuttle and examine the effects of that radiation from a radiation biology viewpoint. The data gathered are analyzed to understand the biological effects as well as the physical nature of the radiation detected.

To accomplish this, a Radiation Monitoring Container Device package is placed on the aft end cone of the Spacelab module, and passive dosimeters are placed in other Spacelab locations. The Radiation Monitoring Container Device consists of layers of solid-state track detectors and biological specimens: maize seeds (*Zea mays*), shrimp eggs (*Artemia salina*), and bacterial spores (*Bacillus subtilis*). The track detectors are sheets of plastic material, called TS-16 and CR-39. The dosimeters are conventional detectors made of lithium fluoride or magnesium-silica-terbium.

Using this equipment, both the amount and trajectory of high-energy radiation can be determined in postflight analysis. The plastic detector sheets record individual nuclear tracks in three dimensions, while the dosimeters give a record of the accumulated radiation energy. The detector sheets are etched chemically to visualize the radiation tracks, the geometric properties of which can reveal the angle of penetration, energy, and whether the particle was a proton or a neutron. By using a computerized microscopic image handler, the radiation path through the Radiation Monitoring Container Device is determined. This allows the biological materials affected by the radiation to be examined during different stages of development so that the effects of the exposure can be observed.

Fluid Therapy System: Inflight Demonstration of the Space Station *Freedom* Health Maintenance Facility Fluid Therapy System

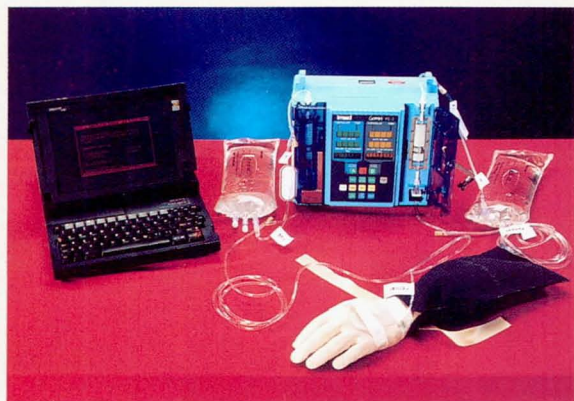
**Dr. Charles W. Lloyd, Principal Investigator
NASA Johnson Space Center (NASA)**

On Earth, when a patient needs fluids, a container of the appropriate solution is hung above the person and a steady drip initiated into a vein. This combination of fluid and delivery is called intravenous (IV) fluid therapy. Under the influence of gravity, fluids flow from the container into the body. But what happens if an astronaut requires an IV in space? How can it be administered without gravity? Where will the bulky fluids be stored?

The answers lie in the Fluid Therapy System, designed specifically for Space Station *Freedom*. This multipurpose unit produces sterile water from onboard water sources, formulates and stores solutions, and infuses the appropriate solution into the patient. By preparing these solutions from concentrates, the need to store bulky and perishable fluids is reduced.

This equipment is being tested on Spacelab J. From 10 liters of source water having a known amount of impurities, the system produces at least 6 liters of purified water. It then formulates various solutions and stores them in sterile containers. To demonstrate IV administration and verify the accuracy of the system pump, which is used in place of gravity, crewmembers administer one solution to a mannequin arm equipped with simulated veins and a solution reception container.

After the mission, investigators analyze the sterile water and solutions to determine both quantity and quality. Any needed changes in the equipment or procedures can be made and tested again before installation onboard Space Station *Freedom*.



The Fluid Therapy System is flying on Spacelab J to test the production and the administration of medical fluids in the microgravity environment.

On Earth, gravity provides the power necessary for IV fluids to flow into a patient. In microgravity, special equipment is needed to get fluids into a patient.



Mission Operations



M A X W E L L

Spacelab J is an ambitious mission. Many investigations must share the same hardware and data-recording equipment, putting constraints on when and how long experiments can run. Some cannot run concurrently because of the vibrations they create or the power they require. The crew must monitor or take part in many of the investigations, making it a very crew-intensive mission.



Technicians assemble equipment racks in the Spacelab J mockup at the Payload Crew Training Complex at the Marshall Space Flight Center.

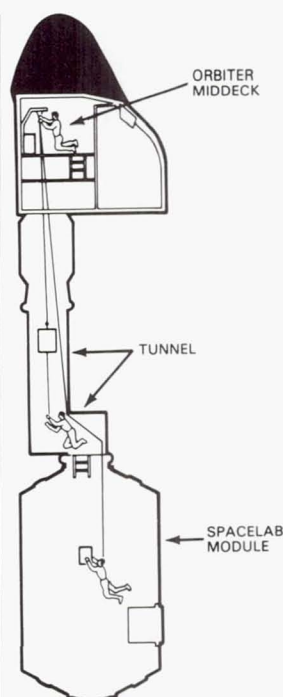
Mission operations could be said to commence more than a year before the launch, when technicians assemble a mockup of the Spacelab J module in the Payload Crew Training Center at Marshall Space Flight Center and the crew and operations cadre begin training. At Kennedy Space Center's Life Science Support Facility, simulations of experiment procedures and processes test, correct, and refine



Technicians check their installation of equipment racks in the Spacelab J mockup.

these operations before the mission.

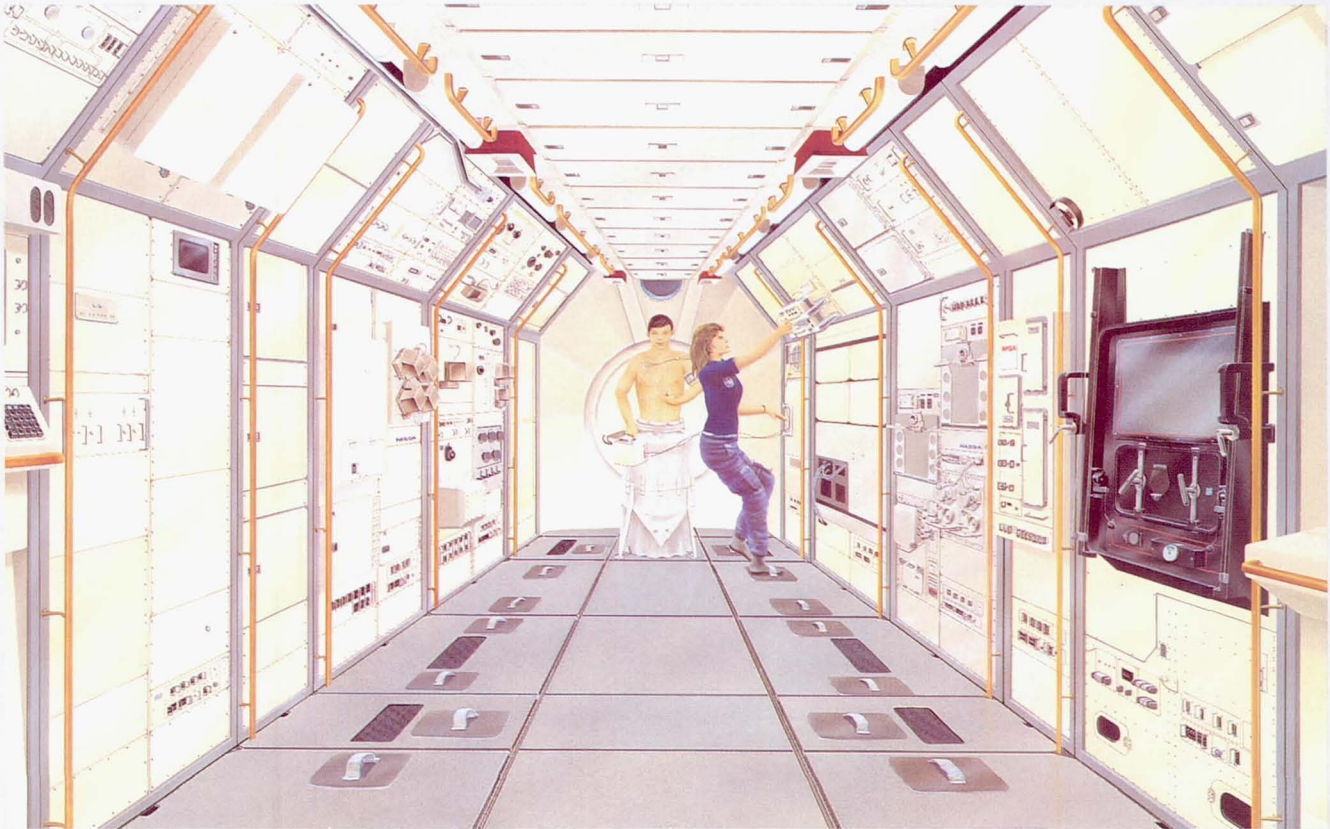
As the year progresses, training staffs conduct simulations in the Payload Crew Training Center, the Mission Control Center at Johnson Space Center, and Spacelab Mission Operations Control at Marshall Space Flight Center. Closer to launch, joint integrated simulations take place, bringing together people in the different ground facilities and the crewmembers to practice mission operations. These simulations prepare the mission team to execute both routine procedures and those required should equipment or systems fail to operate as planned.



Using the Module Vertical Access Kit, a special rig that allows late entry into the Spacelab module, technicians enter the Shuttle shortly before launch to place animals in their middeck and Spacelab accommodations.

Also during this time, crewmembers involved in the human research experiments participate in additional activities at the Baseline Data Collection Facility at Kennedy Space Center. Here, control data are obtained for comparison against data collected during and/or after the mission to determine the various effects of microgravity on the human organism.

Starting approximately 30 hours before launch, technicians load the time-sensitive items for the mission — the frogs, carp, and other materials — into the Spacelab module. Since the orbiter is on the launch pad, the module is in a vertical position. So to load the specimens and samples, a member of the ground crew is lowered into the Spacelab module in a special sling-chair arrangement. This equipment must be removed before storing the protein seed crystals, cell cultures, and other items in the orbiter middeck refrigerator/freezer at approximately 14 hours before launch.



***The flight is controlled by the
Mission Control Center at
Johnson Space Center;
science operations are
controlled from the
Spacelab Mission Operations
Control at Marshall Space
Flight Center.***

Upon reaching the mission's 57-degree, 296-kilometer orbit, crewmembers prepare the Spacelab module for operations and retrieve materials from middeck storage lockers and the refrigerator/incubator and move them to the Spacelab module. The Shuttle is placed in a gravity-gradient attitude for the mission so there are few thruster firings to disturb sensitive experiments such as those growing various crystals. Activation of the Space Acceleration Measurement System experiment occurs approximately 6 hours after launch so acceleration measurements of the Spacelab environment can be made. A number of experiments, especially in the life sciences disciplines, begin less than 7 hours after launch to ensure maximum exposure to the microgravity environment.


The crew works in two shifts, Red and Blue, during the mission. These shifts alternate sleep periods, allowing operations to continue around the clock. The Blue shift sleeps first, starting their sleep period approximately 3 hours after launch. At the end of the mission, the shifts are adjusted so both teams are awake for preparations to leave orbit.

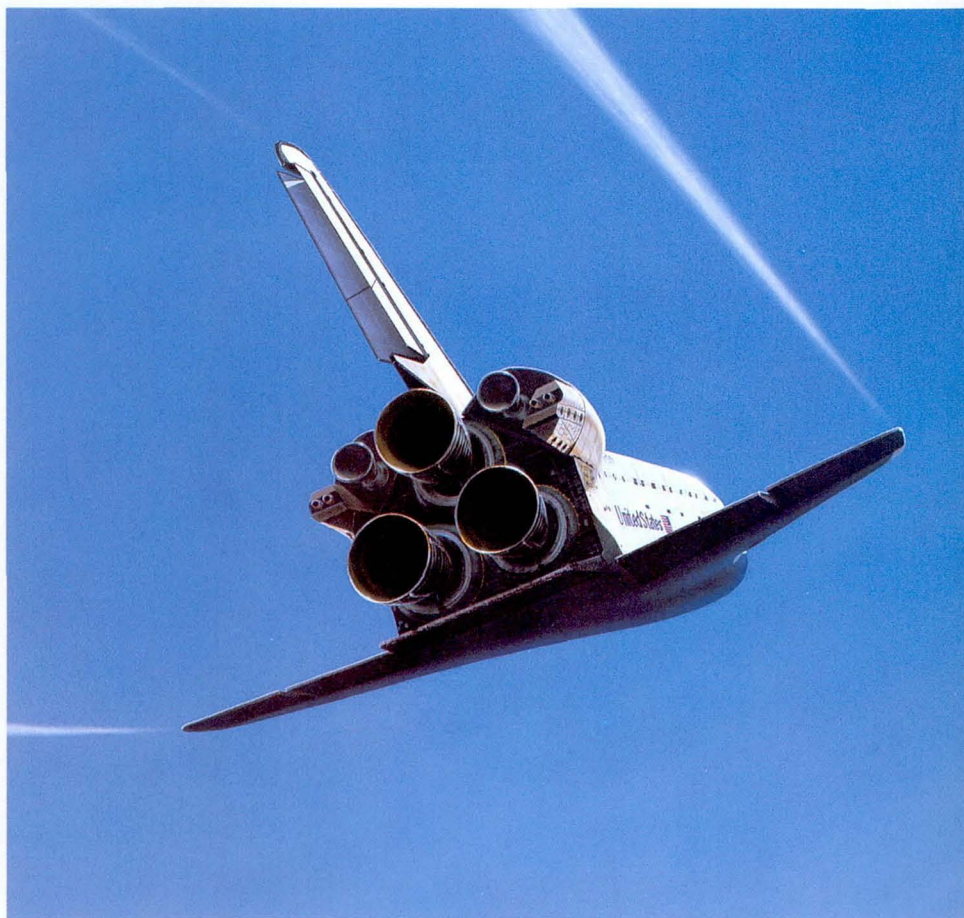
While the flight is controlled by the Mission Control Center at Johnson Space Center, science operations are controlled from the Spacelab Mission Operations Control at Marshall Space Flight Center. This facility is the nerve center for the mission, coordinating communications, receiving engineering and science data, and providing facilities and information to the investigators.

Communications are the key to Spacelab Mission Operations Control activities. From the real-time data received at the facility, the mission manager and his team monitor the mission and make changes in the timeline and activities as required. These same data allow investigators to monitor their experiments, changing procedures or parameters as circumstances dictate. When necessary, scientists can talk directly with the crewmember working on an experiment, taking advantage of a level of interaction almost equal to the investigator being aboard Spacelab.

Spacelab deactivation begins near the end of the sixth day and the crew spends the seventh preparing for landing. Some 3 hours after landing, technicians remove the items stored in the middeck refrigerator/freezer, while the animal experiments are removed within 24 hours of landing.

Initial ground studies of the animal experiments will be conducted at the landing site, along with postflight measurements of the crewmembers involved in the human experiments. It is critical to perform these studies as soon as possible after landing, so that the effects of microgravity on living organisms can be examined before the return to gravity initiates further changes.

If the orbiter does not land at Kennedy Space Center, the rest of the experiment samples are removed for study after the orbiter is returned there. The initial examinations take place at Kennedy's Hangar L, while more detailed studies are conducted at individual research labs. 



The Spacelab J crew reflects the international scope of the mission. Along with the American crewmembers, the first NASDA astronaut will fly as a payload specialist. Trained extensively in the complex operations of the multitude of experiments, the science crew works in concert with the scientists on the ground to attempt to answer a variety of questions and open up entirely new areas in space research.



Captain Robert L. "Hoot" Gibson is the Spacelab J Mission Commander. He joined NASA from the U.S. Navy in January 1978 and qualified as a pilot in August 1979. He

earned his bachelor of science degree in 1969 from the California Polytechnic State University, is a certified test pilot, is a graduate of the Naval Fighter Weapons School ("Topgun"), and has received numerous awards including the Distinguished Flying Cross. Gibson has more than 4,600 hours flight time in more than 45 types of civilian and military aircraft and has a total of 442 hours in space.

He served as pilot of STS 41-B in February 1984, where a variety of projects were performed, including the first use of the Manned Maneuvering Unit (MMU) during an Extravehicular Activity (EVA). He was commander of STS 6-C in January 1986, which deployed a communications satellite and performed experiments in astrophysics and materials processing. He was commander of STS 27 in December 1988, which carried a Department of Defense payload. Spacelab J will be his fourth mission.

Major Curtis L. Brown, Jr., is the Pilot for the mission. He joined NASA in 1987 and completed training in 1988.



He came to NASA from the Air Force where he was serving as a test pilot for the A-10 and F-16 aircraft at Eglin Air Force Base, Florida.

Brown earned a bachelor of science degree in electrical engineering from the U.S. Air Force Academy in 1978 and

began his Air Force career flying the A-10. He was later reassigned as an instructor pilot for the aircraft; then, after attending the Air Force Fighter Weapons School in 1983, he became an instructor in A-10 weapons and tactics. He attended Air Force Test Pilot School in 1985 and, upon his graduation in 1986, was assigned to Eglin Air Force Base. He has more than 3,100 hours of flight time in jet aircraft. Spacelab J will be his first spaceflight.

Dr. Jay Apt is the Flight Engineer for Spacelab J. He joined the NASA astronaut corps in 1985 and completed training in 1986. Before becoming an astronaut, he was a 1976 post-doctoral fellow in laser spectroscopy at the Massachusetts Institute of Technology, a staff member at Harvard University's Center for Earth and Planetary Physics from 1976 to 1980, and assistant director of Harvard University's Division of Applied Sciences from 1978 to 1980. He joined NASA in 1980, working in the Earth and Space Sciences Division of NASA's Jet Propulsion Laboratory. In 1981, he



became science manager for the laboratory's Table Mountain Observatory and in 1982 became a flight controller at the Johnson Space Center.

Apt earned a bachelor of arts

degree in physics from Harvard University in 1971 and his doctorate in physics from the Massachusetts Institute of Technology in 1976. He was a mission specialist on STS-37, the Gamma Ray Observatory mission. During that flight, he performed one scheduled and one unscheduled spacewalk. Spacelab J will be his second mission.

Lt. Colonel Mark C. Lee is the Payload Commander for the mission. A mission specialist, Lee joined NASA in 1984 and completed training in 1985. He joined NASA from the U.S. Air Force where he served as the Flight Commander in the 4th Tactical Fighter Squadron at Hill Air Force Base, Utah.



Lee earned a bachelor of science degree in Civil Engineering from the U.S. Air Force Academy in 1974 and a master of science degree in Mechanical Engineering from the Massachusetts Institute of Technology in 1980. He was awarded the Meritorious Service Medal and two Air Force Commendation Medals. Flying predominately T-38, F-4, and F-16 aircraft, he has logged more than 2,500 hours of flight time. Lee was a mission specialist on STS-30, which deployed the Magellan Venus probe. This will be his second spaceflight.

Dr. Mae C. Jemison, M.D., is the Spacelab J Science Mission Specialist. Dr. Jemison



joined NASA in 1987 and completed training as a mission specialist in 1988. Before becoming an astronaut, she worked in both engineering and medical research in such areas

as computer programming, nuclear magnetic resonance spectroscopy, computer magnetic disc production, and evaluation of trophic factors for rat epididymides. She completed her internship at the Los Angeles County/University of Southern California Medical Center in 1982 and worked as a General Practitioner before becoming the Area Peace Corps Medical Officer for Sierra Leone and Liberia in West Africa. Upon her return to the United States, she joined CIGNA Health Plans of California.

Jemison earned a bachelor of science degree in Chemical Engineering and a bachelor of arts in African and Afro-American Studies from Stanford University in 1977. She earned her doctor of medicine degree from Cornell University in 1981. Spacelab J is her first spaceflight.

Dr. N. Jan Davis is the Mission Specialist assigned to Spacelab J. Davis joined the NASA astronaut corps in 1987 and completed training in 1988. Before becoming an astronaut, she worked at NASA's Marshall Space Flight Center as an aerospace engineer. While there, she worked on the Hubble Space Telescope and the Advanced X-Ray Astrophysics Facility and was the lead engineer for the redesign of the Solid Rocket Booster external tank attachment ring.

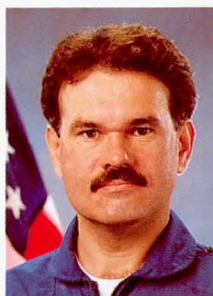
Davis earned a bachelor of science degree in Applied Biology from the Georgia Institute of Technology in 1975, a bachelor of science degree in Mechanical Engineering from Auburn University in 1977, and a master of



science and a doctorate in Mechanical Engineering from the University of Alabama in Huntsville in 1983 and 1985, respectively. Spacelab J is her first spaceflight.

Dr. Stanley N. Koszelak has been designated as Dr. Jemison's backup for the Spacelab J mission. He is a research biochemist at the University of California, Riverside. He has been a co-investigator in previous protein crystal growth experiments flown on the Shuttle.

Koszelak earned a bachelor of science degree in Microbiology from the University of Oklahoma in 1976 and a master of science and a doctorate from the University of Oklahoma Health Sciences Center in 1981 and 1984 respectively.



Dr. Mamoru Mohri is the Japanese Payload Specialist flying on Spacelab J. Dr. Mohri received his doctorate from Flinders University, Australia, in 1976 with major fields of study in surface

physics and ultra-high vacuum science. He studied previously at Hokkaido University, where he completed the master course in physical science.

He taught in the Department of Nuclear Engineering of Hokkaido University from 1975 to 1985, last serving as Associate Professor. He has been an astronaut candidate with NASDA since 1985.

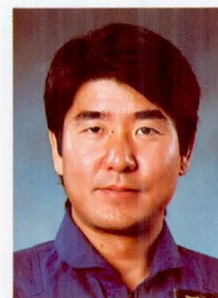
Dr. Chiaki Mukai, M.D., is one of two alternate Japanese Payload Specialists. Dr. Mukai earned the degree of medical doctor from Keio University and passed the National Board for Medical Practitioners exam in 1977. She received a doctorate in physiology from Keio University in 1988.


Dr. Mukai served her residency in general surgery and became an instructor in the Keio University Department of Cardiovascular Surgery in 1979. She has been an astronaut candidate with NASDA since 1985.



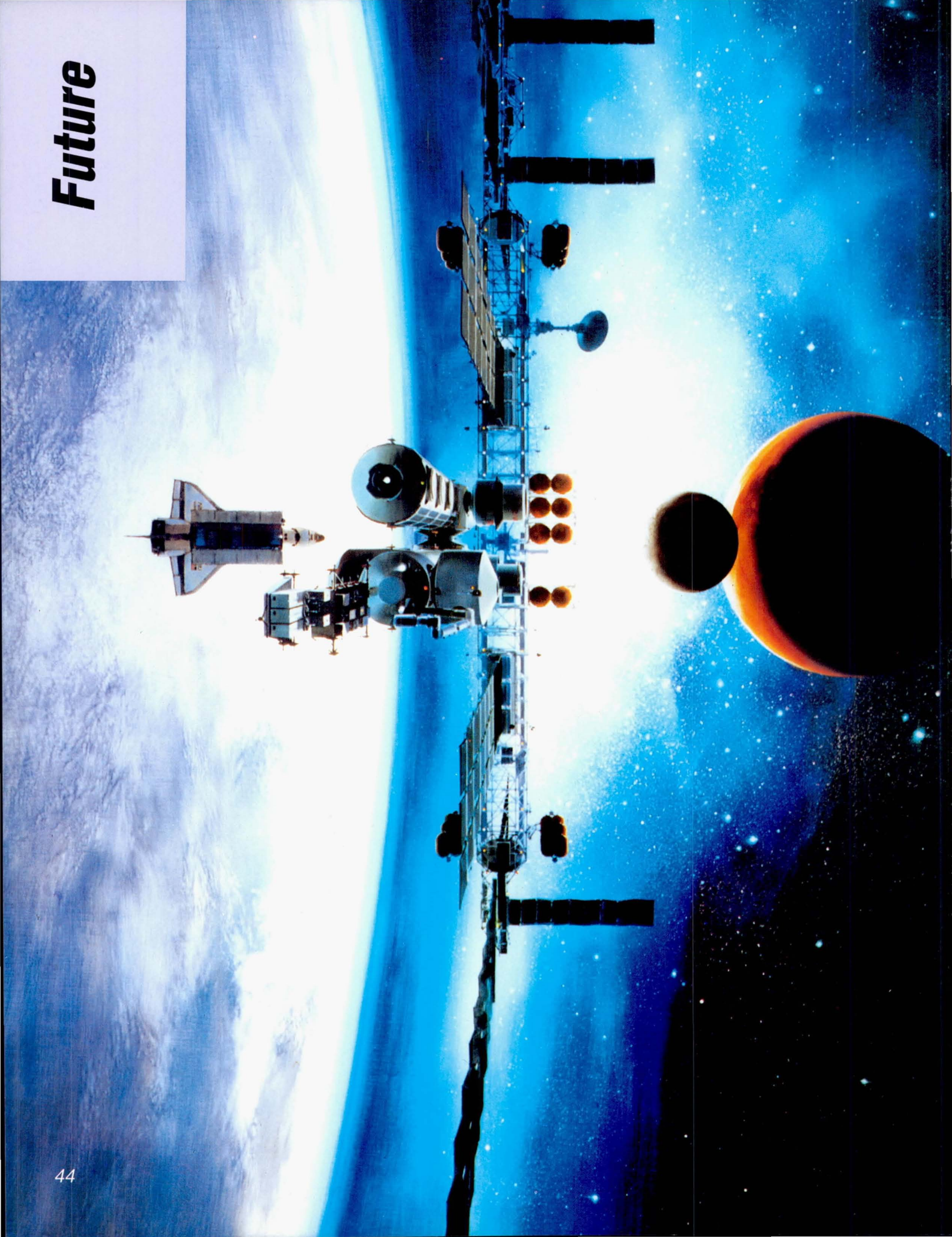
Dr. Takao Doi is the other alternate Japanese Payload Specialist. Dr. Doi received his doctorate in aeronautics from the University of Tokyo in 1983, with his major field of study being space propulsion systems. He had previously earned his master's degree in aeronautics from the University of Tokyo in 1980.

Dr. Doi was a research associate with the Institute of Space and Astronautical Science from 1983 to 1985. In 1985, he served as a National Research Council Research Associate



at NASA's Lewis Research Center until his selection as a NASDA astronaut candidate. 

Future



Can humans live and work for extremely long periods in a weightless environment? Is it possible to perform certain types of research in microgravity that are not possible on Earth? How can microgravity best be used to advance existing fields of research?

These are questions not easily answered. The pursuit of these answers requires repeated experimentation in the microgravity environment across all fields of scientific research. But access to space is limited, and even brief periods of microgravity can be expensive.

Currently, Spacelab missions offer the best opportunity for investigators from around the world to experiment in the microgravity environment. Instead of the minutes obtained by sounding rockets, scientists can have their experiments operate for days. Instead of just a few experiments, several dozen may be performed on a single mission. Through a scientifically trained crew and direct ground commanding, experimental parameters can be changed in response to what is being learned.

The 43 experiments being conducted on Spacelab J are an integral part of developing the answers to the fundamental questions above and to the questions that continued research will raise. The life sciences experiments investigate areas of special concern — bone density loss, Space Adaptation Syndrome, and the development of life in the absence of gravity. The microgravity sciences experiments will provide data on the effectiveness of microgravity for certain research efforts and processes and evaluate new methods for producing improved products.

While no single experiment or bit of data from Spacelab J will provide the ultimate answer to these questions, the information gathered will be combined with data gathered on previous and future missions. Using the combined data, we will obtain the answers to our questions and develop solutions to many of the problems facing us, both on Earth and in space.

Perhaps most importantly, however, Spacelab J will allow the U.S. and Japan, one of its major international space partners, to proceed toward operation of Space Station Freedom. ■

Experiments and Experimenters

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Suggested Terms for Database Searches

Glossary

Acoustic Levitation
Autogenic Feedback
Biofeedback
Biogenic Materials
Containerless Processing
Cosmic Radiation
Developmental Biology
Electrophoresis
Eutectic Alloys
First Material Processing Test (FMPT)
Free Flow Electrophoresis
Gravitational Biology
Hybridoma Cells
Japan, Japanese Space Efforts
Magnetic Resonance Imaging
Marangoni Convection
Materials Processing in
Space/Microgravity/Zero Gravity
Metallic Crystals
Mutation
National Space Development Agency
[of Japan (NASDA)]
Organic Crystals
Pharmaceutical Production in Microgravity
Physiological Development
Radiation
Radiation Protection
Semiconductors
Space Acceleration Measurement System
(SAMS)
Space Adaptation Syndrome (SAS)
Space Biology
Space Medicine
Space Motion Sickness (SMS)
Space Physiology
Spacelab
Spacelab J
Superconductors
Ternary Compounds

The following acronyms and abbreviations are provided as document and mission references. Those not found in this brochure are provided as assistance in monitoring the mission.

ABPS Automatic Blood Pressure System
AFD Aft Flight Deck
AFE American Flight Echocardiograph
AFTE Autogenic Feedback Training Experiment
ALF Acoustic Levitation Furnace
AOS Acquisition of Signal
ARC Ames Research Center
BBU Bubble Behavior Experiment Unit
CCC Cell Culture Chamber
CGF Crystal Growth Experiment Facility
CHF Continuous Heating Furnace
CI Co-Investigator
ECG Electrocardiograph
EKG Electrocardiogram
EMI Electromagnetic Interference
ESA European Space Agency
eV Electron Volt
FEE Frog Embryology Experiment
FEU Frog Embryology Unit
FFEU Free-Flow Electrophoresis Unit
FMPT First Material Processing Test
FPS Fluid Physics Experiment Facility
FTS Fluid Therapy System
GEF Gas Evaporation Experiment Facility
GHF Gradient Heating Furnace
GPWS General Purpose Work Station
GSFC Goddard Space Flight Center
HMF Health Maintenance Facility
IMF Image Furnace
IMU Inertial Measurement Unit
IR Infrared
ISAS Institute of Space and Aeronautical Science
IV Intravenous
IWG Investigator Working Group
JSC Lyndon B. Johnson Space Center
km Kilometer
KSC John F. Kennedy Space Center
kW Kilowatt
l Liter
LBNP Lower Body Negative Pressure Experiment
LBNPD Lower Body Negative Pressure Device

LCC Launch Control Center
LDF Liquid Drop Experiment Facility
LIC Light Impulse Controller
LIF Large Isothermal Furnace
LIS Light Impulse Stimulator
LOS Loss of Signal
m Meter
MCC Mission Control Center
MCU Marangoni Convection Experiment Unit
MD Middeck
MET Mission Elapsed Time
(Time since launch)
mi Mile
MOU Memorandum of Understanding
MMU Manned Maneuvering Unit
MRI Magnetic Resonance Imaging
MS Mission Specialist
MSFC George C. Marshall Space Flight Center
NASA National Aeronautics and Space Administration
NASDA National Space Development Agency of Japan
OCF Organic Crystal Growth Experiment Facility
PCG Protein Crystal Growth Experiment
PCTC Payload Crew Training Complex
PI Principal Investigator
POCC Payload Operations Control Center
PS Payload Specialist
SAMS Space Acceleration Measurement System
SAS Space Adaptation Syndrome
SL Spacelab (Designator denotes specific mission)
SMAC Shuttle Maximum Allowable Concentration
SMS Space Motion Sickness
SSF Space Station Freedom
STS Space Transportation System
SWC Source Water Container
TEI Thermoelectric Incubator
TNSC Tanegashima Space Center
TKSC Tsukuba Space Center
UMS Urine Monitoring System
VFEU Vestibular Function Experiment Unit

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